APPENDIX C

FluidArchitect™ User's Guide/Reference Manual

Copyright

Table of Contents

Preface

What is a Microfluidic Chip?

Fluidigm's technology is the product of highly successful basic research. The Company's technology was developed by researchers at the California Institute of Technology who sought to create assays based on the interactions of individual molecules, cells, viruses and proteins. These assays, and the fluidic technology that enables them, proved overwhelmingly advantageous over their macroscopic counterparts and yielded functionality unavailable until now. These capabilities are the result of breakthroughs in active fluidic devices, surface chemistry, material science, and optical instrumentation. Fluidigm's microfluidic chips provide order of magnitude sensitivity increases and unparalleled flexibility by actively manipulating femtoliters of fluid.

What is FluidArchitect?

FluidArchitect is the design automation applications portion of a revolutionary microfluidics platform that Fluidigm has built and continues to develop. This platform allows the user the ability to design customized microfluidic chips from Fluidigm's library of basic building blocks components with built in rule checking and submit the design for fabrication.

The design automation tool guides the user through the design process setup process and allows the user the ability to simply drag, drop, click, and connect components to form a customized microfluidic chip. User's who are familiar with Microsoft Windows applications will be able to use the FluidArchitect.

FluidArchitect User Requirements

Users of the FluidArchitect design automation application should have the following requirements:

- A good understanding and previous experience with microfluidics
- Experience with computer aided design applications

Chapter 1 – Installati n Process

System Requirements

The following are the system requirements for installing FluidArchitect onto a PC.

- Computer/Processor:
  A Pentium class processor running at 300 MHz processor or higher

- Operating System:
  Windows NT 4.0 or Windows 2000. If you are running a version of Windows NT, you must be running Windows NT Service Pack 3 or higher. If you are running Windows 2000, it is suggested that you are running Windows 2000 Service Pack 1 or higher.

- Memory:
  For Windows NT:
  64 MB of RAM minimum
  For Windows 2000:
  128 MB of RAM minimum

- Hard drive space:
  10 MB

- Mouse:
  Three button mouse. (Mouse with middle scroll wheel is suggested)
  - Left mouse button is used to select or start component/channel
  - Middle mouse button is used to pan in select mode
  - Scroll wheel used to zoom in and out 25% per rotation interval
  - Right mouse button is used to pop up menus in the drawing area

Installing FluidArchitect

FluidArchitect is delivered as an installation package to be executed on the target PC it is to be installed onto. The installation package will automatically guide you through the installation process step by step. All files and libraries will be installed into a directory that can be specified by you.

Requesting a License

Once you have successfully installed the program onto your computer you will need to request a license to unlock the FluidArchitect application in order to use it. The unlock code that will be generated is specifically for the computer the application is installed on. Follow the steps outlined below to request a license for your copy of FluidArchitect.

1. Start the FluidArchitect installer.

2. The InstallShield application will now walk you through the steps of selecting a target directory and installing all the necessary files and directories onto your computer.
3. After finishing installation, go to *Programs* > *Fluid Architect* > *Fluid Architect* under the *Start* menu on your computers desktop to start the FluidArchitect application.

4. Figure 1 shows the dialog box will come up on the first time FluidArchitect is executed. The Site code shown in red is specific to the computer in which the FluidArchitect is being installed.

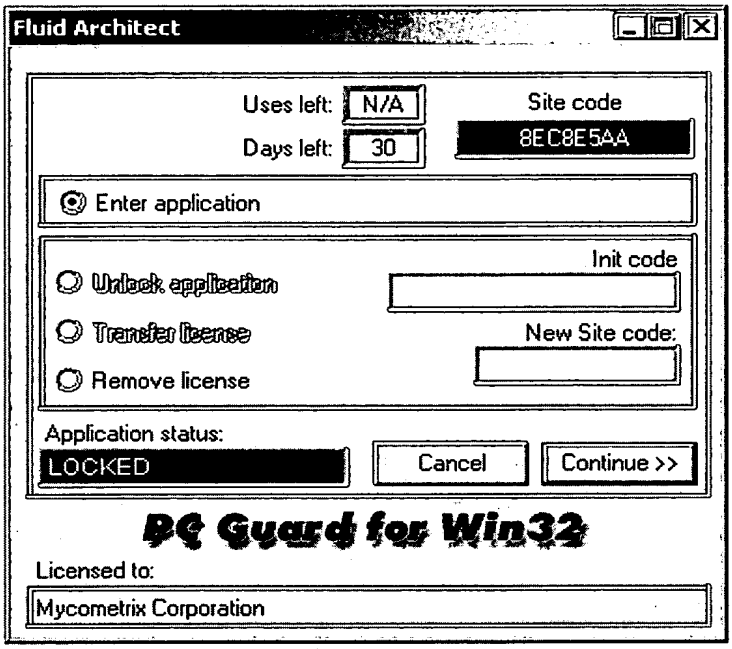


Figure 1 – License Manager

5. Select the Site code and copy the code. Paste the code into an email along with the following information:
   - Contact Name
   - Company
   - Address
   - Phone Number
   - Fax Number (optional)
   - Email Address

6. Email the information to license@fluidigm.com. A license will be generated and emailed back to you typically within 24 hours.

Licensing FluidArchitect

After you have received an email containing your Initialization code, follow the steps below to license FluidArchitect.

1. You will receive a 16 digit alphanumeric string based on the Site code sent in your email.

2. Enter the 16 digit alphanumeric string EXACTLY as it is shown in the email including the "-" character which separates the strings. See Figure 2. In this case the Init code of *TEST-123455678-LOCK* was entered.

3. Click the *Continue* >> button to complete the licensing process.

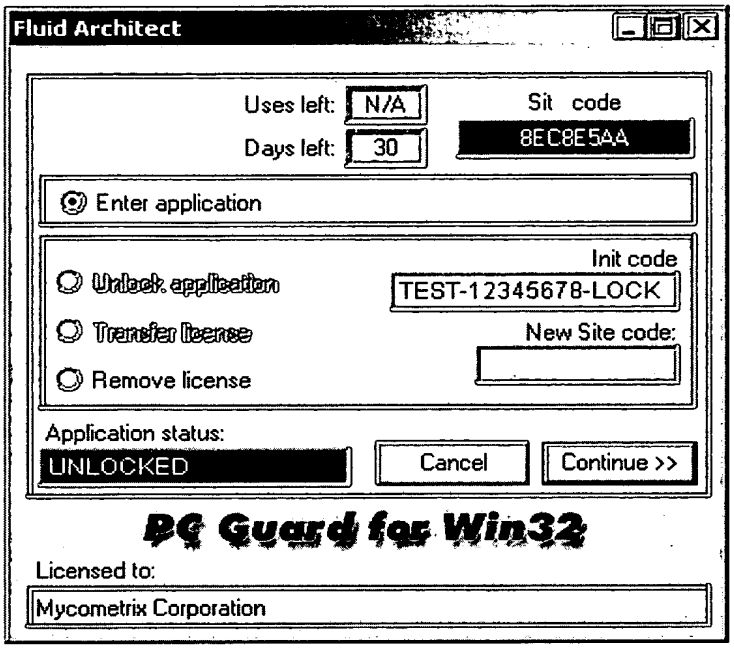


Figure 2 – Dialog to Enter the Init Code

4. After successful entry of the Init code the application is ready for use.

Trouble Shooting Licensing

Check the following items to resolve licensing issues:

- Check the Site code sent to Fluidigm for Init code generation. If the Site code does not match what is displayed in the dialog box then the Init code will not work. Resend the correct Site code for a new Init code following the directions given in the previous sections.

- FluidArchitect has been successfully installed and removed from the computer you are trying to reinstall onto. Once the application has been removed from a computer it is not possible to reinstall and use the old license. A new license must be generated but the existing license from your current working installation must be removed first and verified before a new Init code can be sent.

Chapter 2 – Design Process

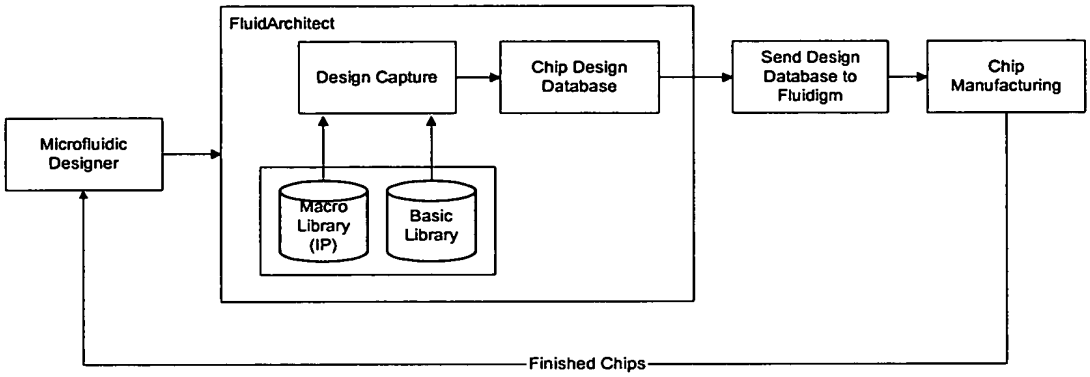


Figure 3 – Microfluidic Chip Design Process with FluidArchitect

Design Flow Process

The design process for designing and building a microfluidic chip is described in Figure 1. Application specific microfluidic chips can be created using the library components provided by Fluidigm. FluidArchitect allows you to capture your design in a simple drag and drop, point and click design environment. Once the design has been completed it is sent to Fluidigm for fabrication. Fabricated devices are sent back to the microfluidic designer for use.

Application Interface

FluidArchitect's interface contains the entire environment in which a design will be started and completed for submission to Fluidigm for fabrication.

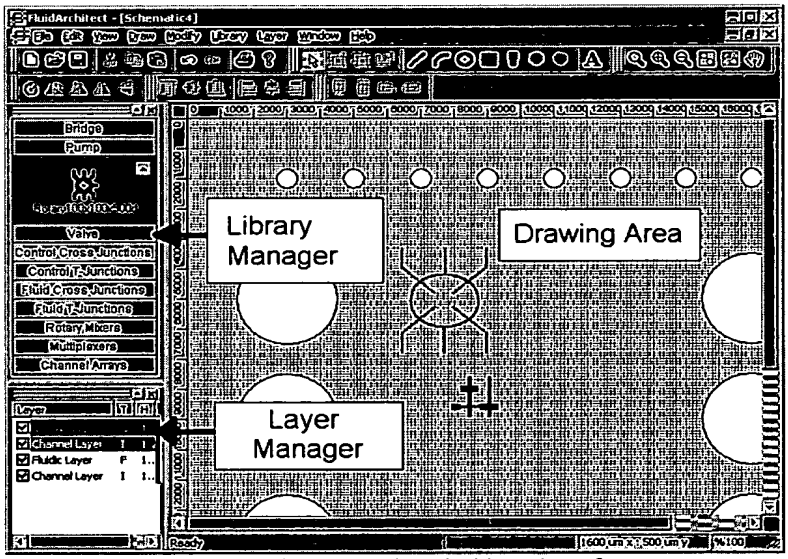


Figure 4 – FluidArchitect's User Interface

The user interface has three primary components: *Library Manager*, *Layer Manager*, and *Drawing Area* (see Figure 4).

Library Manager

The component libraries come predefined and are installed with the FluidArchitect application. The library components are tested and approved for use in the microfluidic chip making process. These libraries will be updated with new components as they are approved from Fluidigm for use. The component library will be delivered as part of a new release or

delivered as a separate library installation. Components can be "dragged and dropped" from the *Library Manager* onto the *Drawing Area* to be added as part of a design.

Layer Manager
The *Layer Manager* can be used to control the viewing of the layers as well as the properties of the layers. The color representations of the layers are shown in the manager and can be changed as part of the layer properties. Currently the number of layers is limited to two and channel heights per layer is limited one.

Drawing Area
The *Drawing Area* is where the design is created using components from the *Library Manager* and interconnected with the channel drawing tools. The *Drawing Area* is a WYSIWYG representation of the layout of the microfluidic circuit that will be fabrication and represents the standard 20 mm x 20 mm chip outline.

Basic Design Operations

Starting a New Project

To start a new project click **New** button,  , in the **File** toolbar or use the **File** > **New** menu command. FluidArchitect will start the Design Wizard to help setup a new project. The Design Wizard will ask you to select or set the following items:

- Project Directory
- Chip Template
- Layers of the Chip

Once the Design Wizard was collected all of the needed information, the chosen chip template with the appropriate settings will be displayed in the *Drawing Area* of the FluidArchitect application.

Opening an Existing Project

To open an existing project use the **File** > **Open** menu command. The **File** menu will also show the four most recent projects that have been opened just above the **Exit** command. These recently opened projected can be quickly opened by simply selected them in the menu.

Loading the Libraries

The initial set of libraries will be installed with the installation of the FluidArchitect application. Should additional libraries be available from Fluidigm, the libraries can be simply added using the **Library** menu.

Saving a Design Project

The project can be saved at any point by using the **File** > **Save** or **File** > **Save As...** menu command. The project is saved with a *.mdx file extension and this file can be sent to Fluidigm for chip fabrication once the design has been completed.

> **Note – It is strongly suggested that a back up of the *.mdx file is saved periodically. The *.mdx file contains the complete database of the design project.**

Submitting a Design Databas for Fabrication

Once the design has been completed and verified free of errors it can be submitted to Fluidigm for fabrication. The design database can be found in the directory that the design was created in. The file extension of the design database is **.mdx*. This file can be sent to manufacturing@fluidigm.com along with your contact information. A representative from Fluidigm will contact you regarding the details of your order for fabrication.

Chapter 3 – Design Editor Reference

Introduction

The goal of the design editor is to help you design effectively and as efficiently as possible. The libraries that are built into FluidArchitect represent microfluidic structures that are approved for implmentation in Fluidigm's processes. "Channel" drawing tools are provided to connect the microfluidic structures available from the libraries. The sections below will described the design editor in detail.

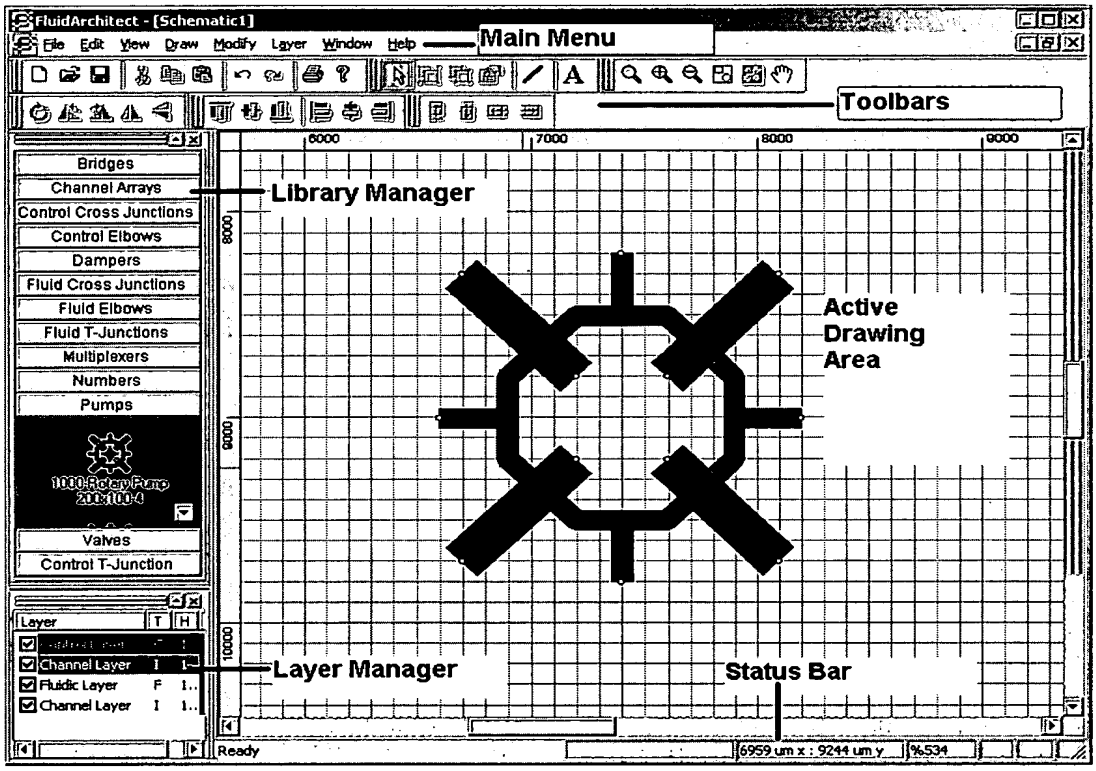


Figure 5 – FluidArchitect Main User Interface (Main Menu, Toolbars, Library Manager, Layer Manager, and Active Drawing Area)

Menus

Main Menu

The main menu is composed of nine menu groups which group related operations and commands for the application.

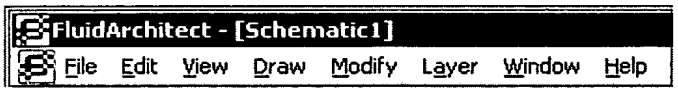


Figure 6 – Main Menu Bar

File Menu

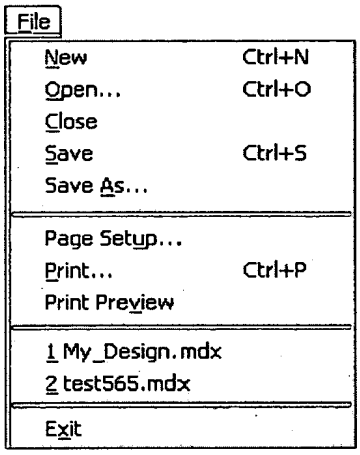


Figure 7 – File Menu Commands

File > New
The *New* command starts the Design Wizard which will automatically set up the design project. (see Creating a Design for more details on the Design Wizard).

File > Open...
The *Open* command opens an existing design which has been saved.

File > Close
The *Close* command closes the active design project in the application. Closing a design project will safely close and exit the application. If any changes were made to the active design, you will be asked whether or not you want to continue to close the design.

File > Save
The *Save* command saves the active design project in the application. Saving the design will save the design project and close the project.

File > Save As...
The *Save As...* command saves the active design project in the application. This command allows you to save the design project under a different name or directory location other than the current location where the file is saved.

File > Page Setup
The *Page Setup* command allows you to set the print options for the active design project.

File > Print
The *Print* command will print the active design project and scale the design to fit the selected Paper size for the Printer.

File > Print Preview
The *Print Preview* command will preview a print of the active design project to the screen.

Edit Menu

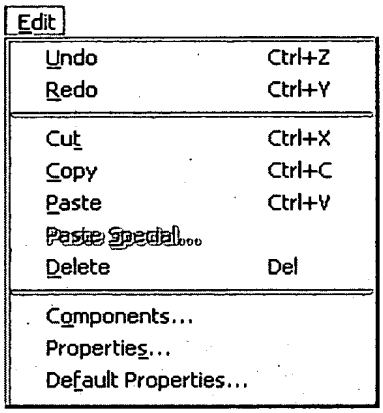


Figure 8 – Edit Menu Commands

Edit > Undo
The *Undo* command will undo the last command you executed on the active design project.

Edit > Redo
The *Redo* command will reverse the last command *Undo* command you executed on the active design project.

Edit > Cut
The *Cut* command cuts and pastes all selected components in the drawing area into the Clipboard.

Edit > Copy
The *Copy* command copies and pastes all selected components in the drawing area into the Clipboard.

Edit > Paste
The *Paste* command will paste the contents of the Clipboard into the drawing area. Only objects using the *Cut* or *Copy* command can be pasted from the Clipboard.

Edit > Paste Special
Not Currently Defined.

Edit > Delete
The *Delete* command is used to delete any selected object in the active drawing area.

Edit > Components
The *Components* command will bring up the Components dialog box. The dialog box, Figure 5, will show all of the components that are currently placed into the active drawing area.

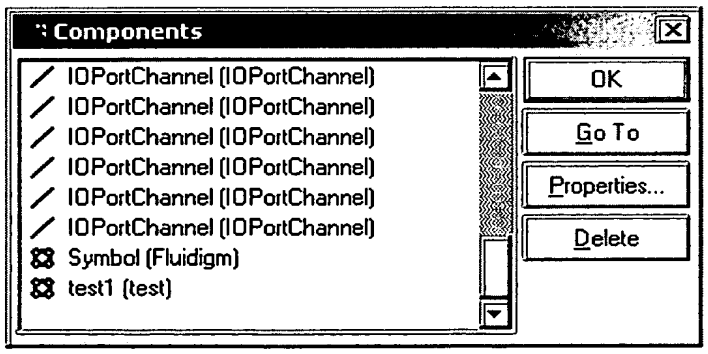


Figure 9 – Component Dialog Box

Additional commands available from this dialog box are:

- *OK* – Closes the dialog box
- *Go To* – Not currently implemented
- *Properties* – Opens the Properties dialog sheet for the component
- *Delete* – Not currently implemented

Edit > Default Properties

The *Default Properties* command will bring up the Properties dialog box for the entire design. The dialog box, Figure 6, will show all of the default settings for the design

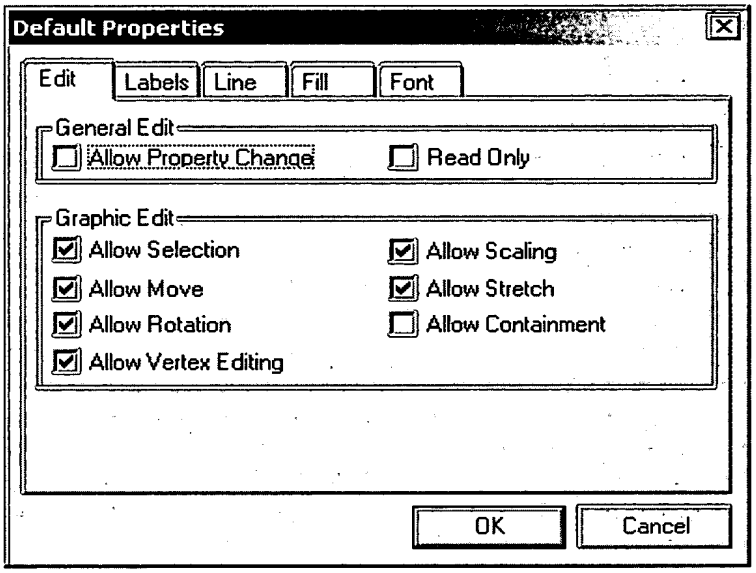


Figure 10 – Default Properties Dialog Box

- *OK* – Closes the dialog box and save any changes
- *Cancel* – Closes the dialog box and discards changes
- *Edit tab* – Not currently implemented
- *Labels* – Sets the label orientation for components
- *Line* – Not currently implemented
- *Fill* – Not currently implemented
- *Font* – Sets the fonts options for the labels

View M nu

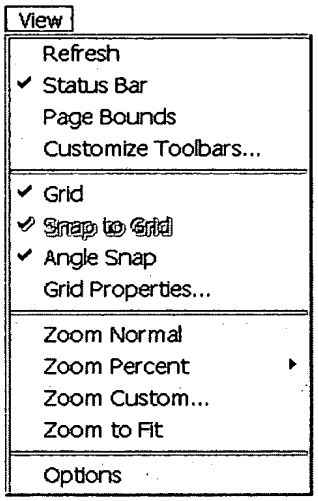


Figure 11 – View Menu Commands

View > Refresh
The *Refresh* command will redraw the active drawing area. Sometimes the drawing area may not refresh completely during editing of the design leaving screen artifacts. The *Refresh* command can be used to redraw the screen to eliminate the artifacts. Note that the artifacts will not be saved into the design.

View > Status Bar
The *Status Bar* command can be used to display or remove the status bar in the lower right corner of the application. The Status Bar, Figure 12, shows the selected component, the screen location of the cursor, and the percent zoomed.

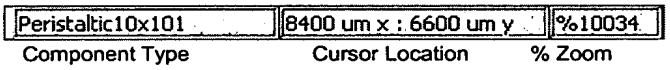


Figure 12 – Status Bar

View > Page Bounds
The *Page Bounds* not currently implemented.

View > Customize Toolbars...
The Customize Toolbars... allow you to show or hide the toolbar tool bars in the application window directly under the Main Menu bar. Figure 13 shows the dialog box that appears when this command is selected. All of the toolbars, including the Main Menu bar, can be displayed or hidden based on settings made through this dialog box with the Toolbars tab selected.

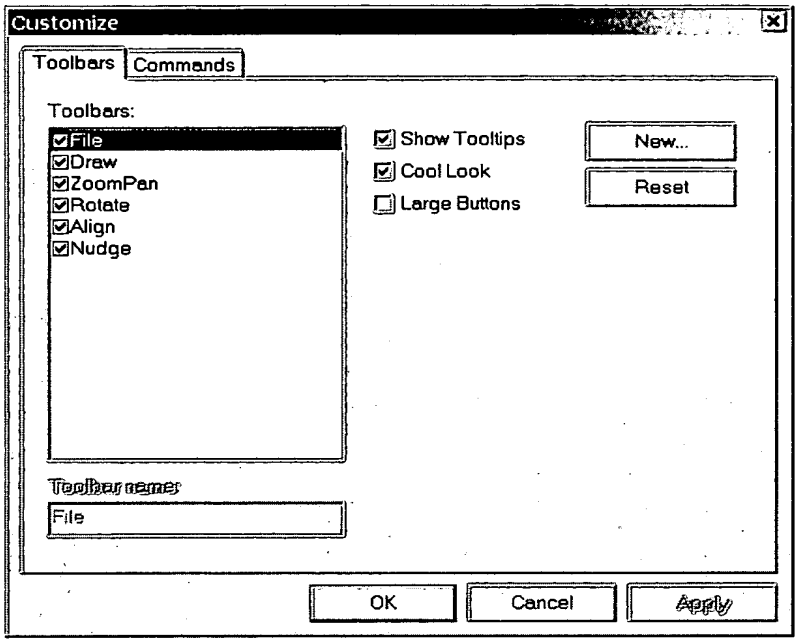


Figure 13 – Customize Toolbars Dialog Box with Toolbars tab selected

The toolbars can be customized by dragging and dropping commands icons from the dialog box directly into the existing toolbars present in the application. Figure 14 shows the "Buttons" or commands that can be left click and dragged to the toolbars.

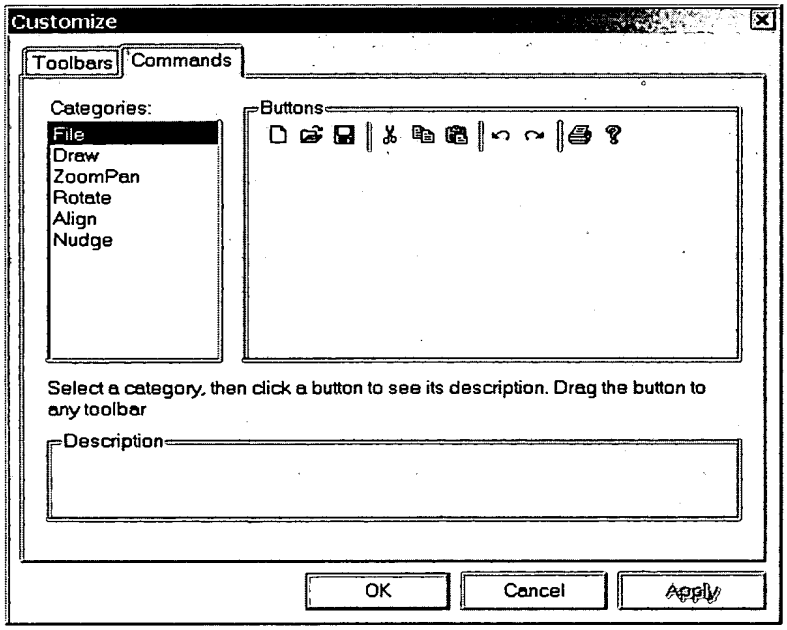


Figure 14 – Customized Toolbars Dialog Box with Commands tab selected

View > Grid
The *Grid* command enables or disables the grid to be displayed in the active drawing area.

View > Grid Pr perties...
The *Grid Properties...* command will bring up the dialog box, Figure 15. The Grid dialog box allows you to set the grid color and the intervals at which the grid is rendered and also to enable or disable the grid from the drawing area.

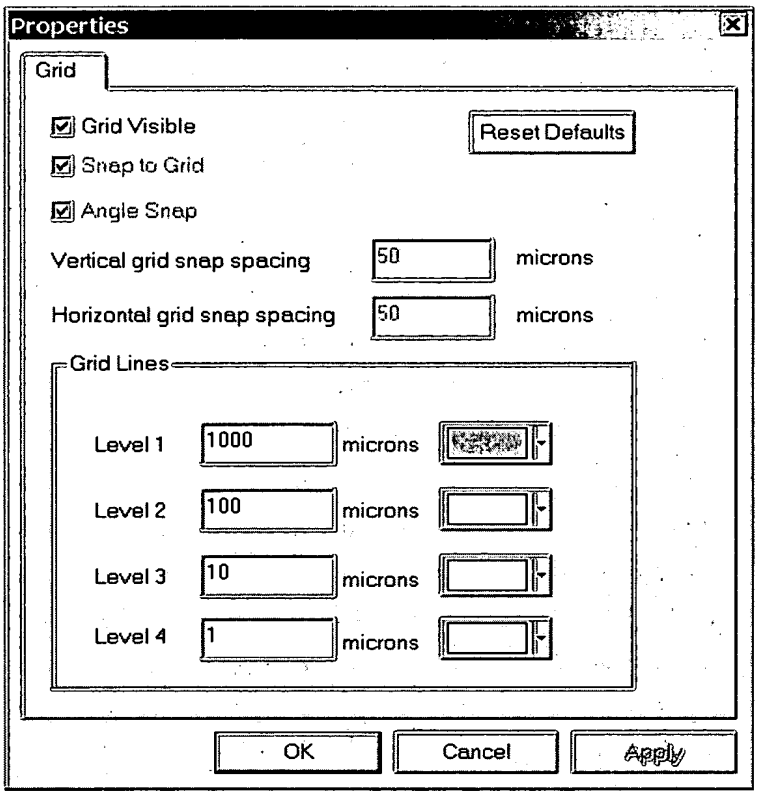


Figure 15 – Grid Properties Dialog Box

View > Zoom Normal
The *Zoom Normal* command will zoom the view of the active drawing area to view the entire chip.

View > Zoom Percent
The *Zoom Percent* command allows you to select *50%, 75%, 100%*, and *200%* zoom of the active drawing area.

View > Zoom Custom...
The *Zoom Custom...* command allows you to select *50%, 75%, 100%*, and *200%* from the drop down box and you can also enter in your own zoom factor of the active drawing area.

View > Zoom Fit
The *Zoom Fit* command will zoom the view of the active drawing area to view the entire chip.

View > Options
The *Options* command will bring up the *Grid* and *Library* dialog box, Figure 16. The Grid properties are the same as those in the *View > Grid Properties...*

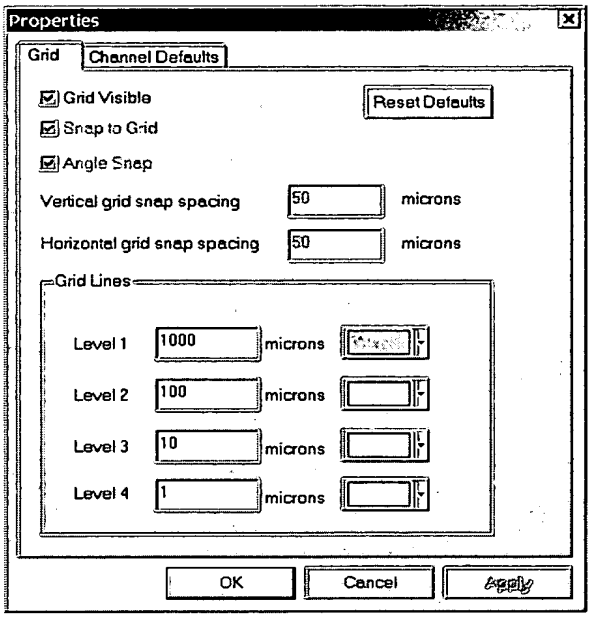


Figure 16 – Grid and Channel Defaults Dialog Box

The Channel Defaults allow you to set the default channel widths for the fluidic and the control layer channels that are draw to interconnect the library components. Figure 17 shows the dialog box with the Channel Defaults tab selected.

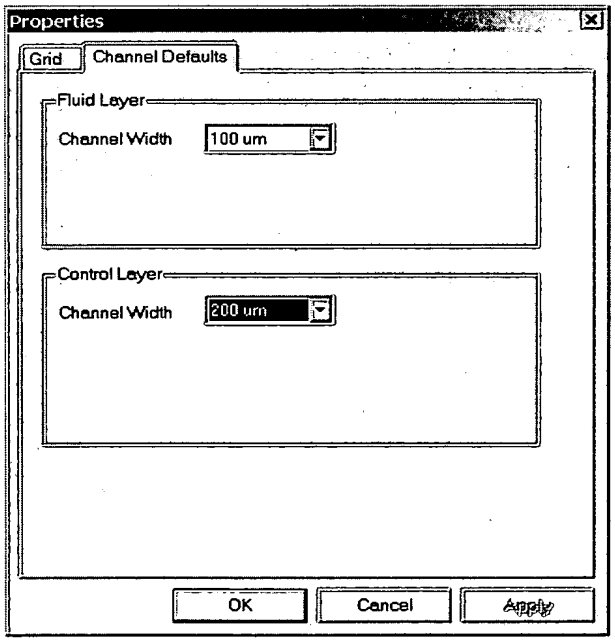


Figure 17 – Channel Defaults Selection Dialog Box

The drop down boxes allows you to set the default width of the channel that you draw on both the fluidic and control layer. Keep in mind that any drawn channel's width can be changed using the Property sheet for each channel.

Draw Menu

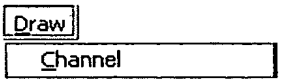


Figure 18 – Draw Dialog Box

Draw > Channel
The *Channel* command places the mode of the active drawing area into drawing channels. A drawn channel will be to the layer that is currently "Active". A layer can be set active in two methods: enabling the layer to be active through the *Library Manager*, Figure 12, or through a right mouse click while in the active drawing area with the *Select* tool selected. Select the *Layers* command to set the desired layer, Figure 19.

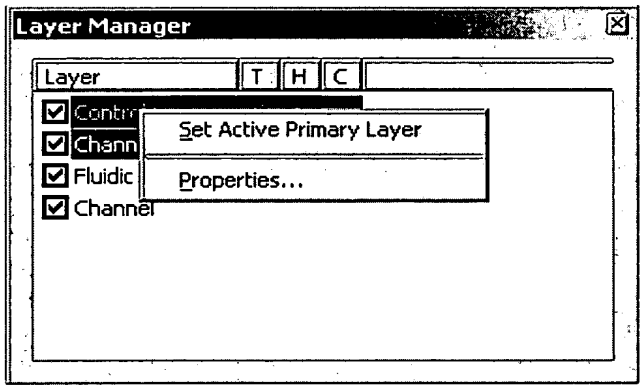


Figure 19 – Library Manager Window

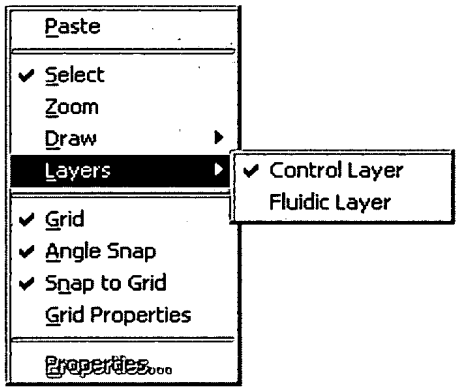


Figure 20 – Right Click Pop Up Menu in Drawing Area

Modify Menu

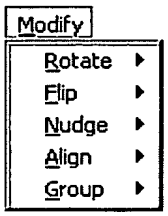


Figure 21 – Modify Menu Commands

M dify > Rotate
The *Rotate* command contains a submenu of commands, Figure 22, which can be performed on a selected object(s) in the active drawing area.

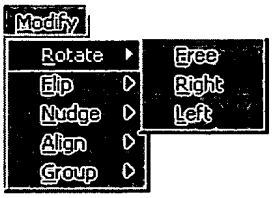


Figure 22 – Rotate Submenu Commands

Modify > Rotate > Free
The *Free* command allows you to freely rotate the selected object(s). Depending on the properties of the object it may or may not be enabled to rotate. Note that rotating objects can cause ports of components and channels to become detached from the grid making it difficult to connect channels.

Modify > Rotate > Right
The *Right* command allows you to rotate the selected object(s) clockwise 90 degrees.

Modify > Rotate > Left
The *Left* command allows you to rotate the selected object(s) counterclockwise 90 degrees.

Modify > Flip
The *Flip* command contains a submenu of commands, Figure 23, which can be performed on a selected object(s) in the active drawing area.

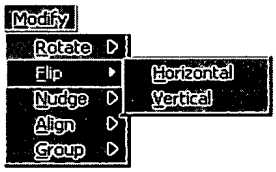


Figure 23 – Flip Submenu Commands

Modify > Flip > Horizontal
The *Horizontal* command allows you to flip the selected object(s) about a horizontal axis. Note that selected objects not grouped together will be flipped about the objects horizontal axis.

Modify > Flip > Vertical
The *Vertical* command allows you to flip the selected object(s) about a vertical axis. Note that selected objects not grouped together will be flipped about the objects veritcal axis.

Modify > Nudge
The *Nudge* command contains a submenu of commands, Figure 24, which can be performed on a selected object(s) in the active drawing area. The Nudge command can be used to move selected object(s) back onto the grid to help connecting to other channels or components on the grid.

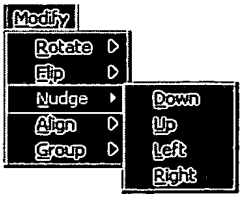


Figure 24 – Nudge Submenu Commands

Modify > Nudge > Down
The *Down* command allows you to move the selected object(s) down one micron in the active drawing area. Holding the Shift key while executing this command will move the object 5 microns.

Modify > Nudge > Up
The *Up* command allows you to move the selected object(s) up one micron in the active drawing area. Holding the Shift key while executing this command will move the object 5 microns.

Modify > Nudge > Left
The *Left* command allows you to move the selected object(s) left one micron in the active drawing area. Holding the Shift key while executing this command will move the object 5 microns.

Modify > Nudge > Right
The *Right* command allows you to move the selected object(s) right one micron in the active drawing area. Holding the Shift key while executing this command will move the object 5 microns.

Modify > Align
The *Align* command contains a submenu of commands, Figure 25, which can be performed on a selected object(s) in the active drawing area.

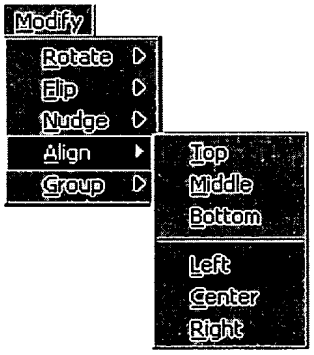


Figure 25 – Align Submenu Commands

Modify > Align > Top
The *Top* command allows you to select a group of objects in the active drawing area and have the top of the objects aligned together.

Modify > Align > Middle
The *Middle* command allows you to select a group of objects in the active drawing area and have all of the objects aligned to horizontal middle.

Modify > Align > Bottom
The *Bottom* command allows you to select a group of objects in the active drawing area and have the bottom of the objects aligned together.

Modify > Align > Left
The *Left* command allows you to select a group of objects in the active drawing area and have all of the objects aligned to the left.

Modify > Align > Center
The *Center* command allows you to select a group of objects in the active drawing area and have all of the objects aligned to vertical center.

Modify > Align > Right
The *Right* command allows you to select a group of objects in the active drawing area and have all of the objects aligned to the right.

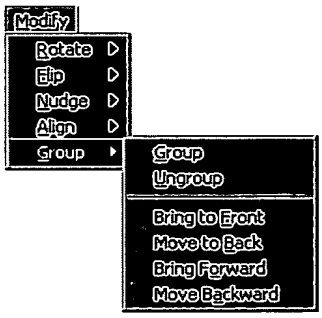


Figure 26 – Group Submenu Commands

Modify > Group
The *Group* command allows you to select a group of objects in the active drawing area and group the objects into a single entity or the ability to select a grouped object and ungroup them into their original components.

Modify > Group > Group
The *Group* command allows you to select a group of objects in the active drawing area and group the objects into a single entity.

Modify > Group > Ungroup
The *Group* command allows you to select a grouped object in the active drawing area and ungroup the objects back to their stand alone state.

Modify > Group > Bring to Front
Not Currently Implemented

Modify > Group > Move to Back
Not Currently Implemented

Modify > Group > Bring Forward
Not Currently Implemented

Modify > Group > Move Backward
Not Currently Implemented

Layer Menu

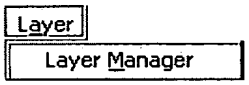


Figure 27 – Layer Menu Command

Layer Manager
The *Layer Manager* command brings up the Layer Manager dialog box as shown in Figure 27.

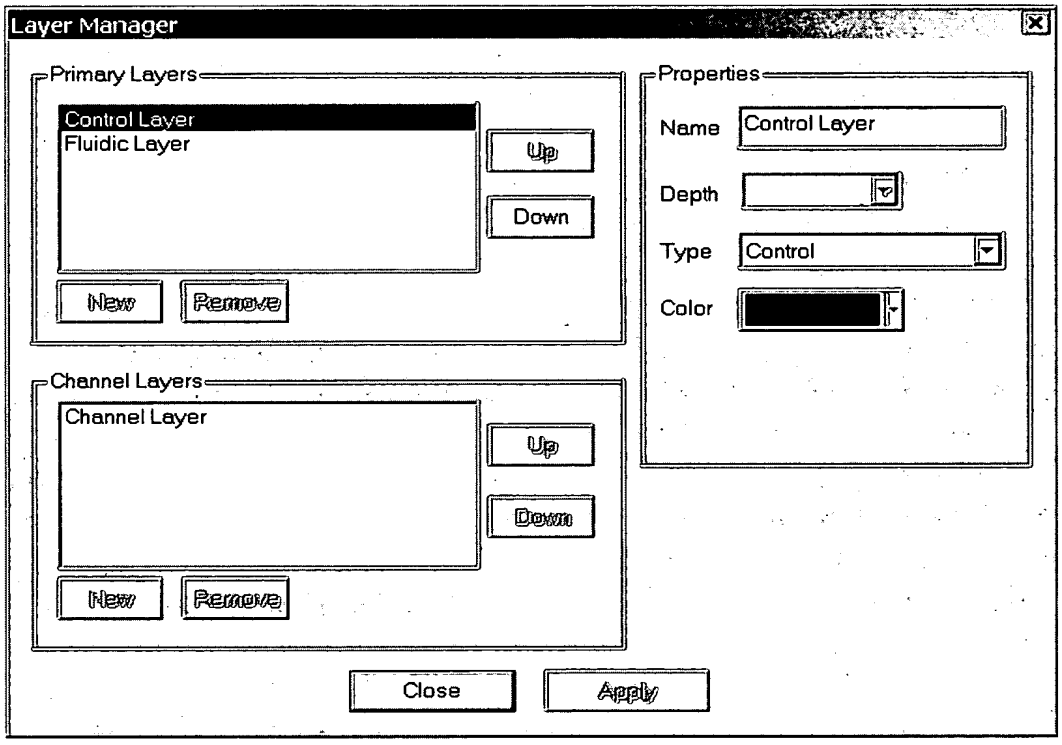


Figure 28 – Layer Manager Dialog

Primary Layers
The *Primary Layers* section of the dialog box shown in Figure 28 shows the total number of layers present in the design. Currently it is not possible to change the *Name* nor the *Depth* of these primary layers. You can change the color of the layers in the *Properties* section of the dialog box once the primary layer is selected. Click on the *Apply* button after any changes are made to save the changes.

Channel Layers
The *Channel Layers* section of the dialog box shown in Figure 28 shows the total number of channel depths available in one primary layer. Currently this is set to one channel depth per primary layer. You can change the name of the channel layer by left clicking on the layer name to select it in the Channel Layers section of the dialog and then entering in a new name in the *Properties* section. Click on the *Apply* button after any changes are made to save the changes. Also note that the channel depth is shown for the layer once it has been selected.

Window Menu

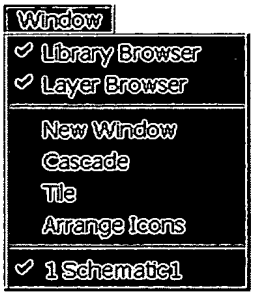


Figure 29 – Window Menu Commands

Window > Library Browser
This command close or open the Library Manager window. A check mark indicates that it is currently displayed.

Window > Layer Browser
This command close or open the Layer Manager window. A check mark indicates that it is currently displayed.

Window > New Window
This command will open up another drawing window with a copy of the design in the active drawing window.

Window > Cascade
This command will cascade all open design drawing windows in the application.

Window > Tile
The command will tile all open design drawing windows in the application.

Window > Arrange Icons
The command will arrange all iconified design drawing windows in the application and align them to the bottom of the drawing window area.

Help Menu

Figure 30 – Help Menu Command

The Help Menu currently only displays the version number of the application.

Toolbars

The tool bars shown in Figure 31 replicate much of the functionality that can be found in the Main Menu system but are readily accessible without having to select the menu to find the needed command.

There are a total of six toolbars that are set to appear upon the start of FluidArchitect: *File, Drawing, ZoomPan, Rotate, Align,* and *Nudge.* Each of these toolbars consist of a set of icons which represents a function that can be performed either on a selected object or on the design project itself.

D cking and Undocking
The tool bars initially are docked under the Main Menu system. As with typical Windows applications, the toolbars can be selected and undocked to float above the application for

easier access. At anytime the toolbars can be "re-docked" back under the Main Menu by simply left clicking the mouse over the undocked toolbar and dragging it back to the docked area of the other toolbars.

***File* Toolbar**

Figure 31 – File Toolbar

Toolbar Command	Command
	New– Opening a new design database and starts the Design Wizard to walk you through the setup.
	Open– Opens an existing design database.
	Save– Saves the design database of the active drawing window.
	Cut – Cuts any selected object(s) in the active drawing window and saves it to the system clipboard.
	Copy – Copies any selected object(s) in the active drawing window and saves it to the system clipboard.
	Paste – Pastes a item from the system clipboard into the active drawing window. Note: It is not advisable to paste objects other than those cut or copied from the FluidArchitect application.
	Undo – Undoes the last command performed. Repeated undo can be performed.
	Redo – Redoes the last undo command.
	Print – Prints a scaled copy of the design to the printer. The scaled design will be scaled to best fit the standard size printer page.
	Help – Brings up the "About FluidArchitect" dialog with the release information.

Table 1 – File Toolbar Commands

Drawing Toolbar

Figure 32 – Drawing Toolbar

Toolbar Command	Command
	Select – Opening a new design database and starts the Design Wizard to walk you through the setup.
	Group – Groups selected objects in the active drawing window.
	Ungroup – Ungroups objects that were previously grouped together using the *Group* command.
	Properties – Displays the properties of a selected component/channel in the active drawing window.
	Draw Channel – Places the mode of the active drawing window in the mode of drawing channels. Once this command is selected the tool remains in this mode until it is unselected through selecting another command. Right clicking twice in the active drawing area will switch the mode of the drawing area back to the *Select* mode.
	Text – The text tool can be used to place notes in the active drawing window. Note: Text is NOT rendered onto the final output of the chip design.

Table 2 – File Toolbar Commands

Zoom Pan To Ibar

Figure 32 – Zoom Pan Toolbar

Toolbar Command	Command
	*Zoom* – This command places the active drawing window in the zoom mode and the cursor becomes a magnifying glass icon. Click and hold the left mouse button and drag to form a rectangle over the area you wish to zoom into.
	*Zoom in 25%* – This command zooms in the active drawing area in by 25%.
	*Zoom out 25* – This command zooms out the active drawing area by 25%.
	*Zoom to Fit* – This command zooms the active drawing area to fit the entire chip to the display area.
	*Zoom to Selection* – This command zooms the active drawing area to fit the selected objects to the display area.
	*Pan*– This command places the active drawing window in the pan mode and the cursor becomes a hand icon. Click and hold the left mouse button to pan the active drawing area is the direction desired.

Table 3 – Zoom Pan Toolbar Commands

Rotate Toolbar

Figure 33 – Rotate Toolbar

Toolbar Command	Command
	*Rotate* – The command is used to freely rotate a selected object in the active drawing area. Note: This command should be used carefully as freely rotating objects can cause the connecting point/ports to become "off-grid" making it impossible to connect other components and channels to it.
	*Rotate Left* – This command rotates a selected object in the active drawing area 90 degrees counter clockwise.
	*Rotate Right* – This command rotates a selected object in the active drawing area 90 degrees clockwise.
	*Flip Vertical* – This command flips a selected object in the active drawing about its vertical center axis.
	*Flip Horizontal* – This command flips a selected object in the active drawing about its horizontal center axis.

Table 4 – Rotate Toolbar Commands

Align Toolbar

Figure 34 – Align Toolbar

Toolbar Command	C mmand
	*Align Top* – The *Top* command allows you to select a group of objects in the active drawing area and have the top of the objects aligned together.
	*Align Middle* – The *Middle* command allows you to select a group of objects in the active drawing area and have all of the objects aligned to horizontal middle.
	*Align Bottom* – The *Bottom* command allows you to select a group of objects in the active drawing area and have the bottom of the objects aligned together.
	*Align Left* – The *Left* command allows you to select a group of objects in the active drawing area and have all of the objects aligned to the left.
	*Align Center* – The *Center* command allows you to select a group of objects in the active drawing area and have all of the objects aligned to vertical center.
	*Align Right* – The *Right* command allows you to select a group of objects in the active drawing area and have all of the objects aligned to the right.

Table 5 – Align Toolbar Commands

Nudge Toolbar

Figure 35 – Nudge Toolbar

Toolbar Command	Command
	*Nudge Up* – The *Up* command allows you to move the selected object(s) up one micron in the active drawing area. Holding the Shift key while executing this command will move the object 5 microns.
	*Nudge Down* – The *Down* command allows you to move the selected object(s) down one micron in the active drawing area. Holding the Shift key while executing this command will move the object 5 microns.
	*Nudge Left* – The *Left* command allows you to move the selected object(s) left one micron in the active drawing area. Holding the Shift key while executing this command will move the object 5 microns.
	*Nudge Right* – The *Right* command allows you to move the selected object(s) right one micron in the active drawing area. Holding the Shift key while executing this command will move the object 5 microns.

Table 6 – Nudge Toolbar Commands

Library Manager

The Library Manager is show in Figure 36. This window of the FluidArchitect application contains the library components that are available for your design.

Use of the Library Manager is simple and straightforward. To select the library desired, simply left click on the title of the library and the components will be displayed. If more than one component is present in the library use the up or down button to scroll through them.

Once the proper component is found, left click the mouse button and hold and drag the component into the active drawing area and release the button to place the component.

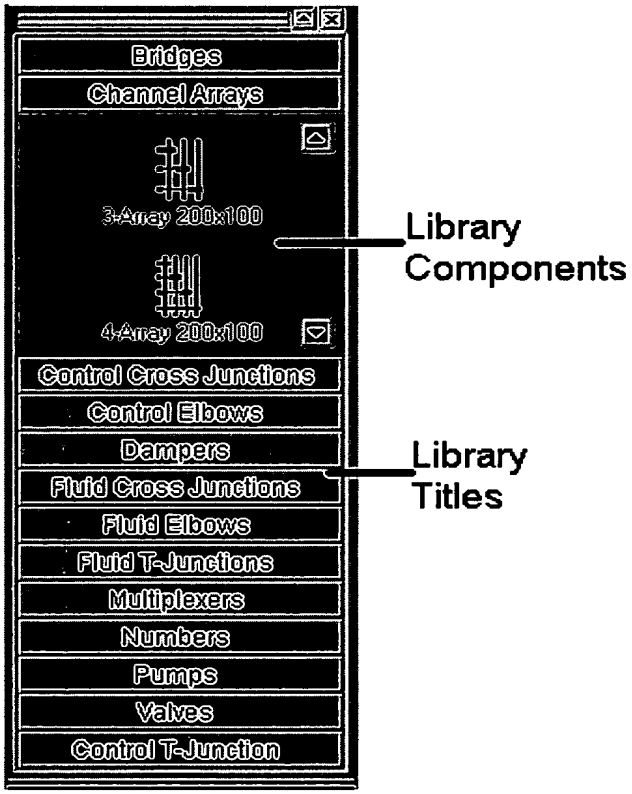


Figure 36 - Library Manager Window

Please refer to the **Fluidigm Databook** for a list of available library components along with their description and specifications.

Library Component Characteristics
A library component is typically composed of channels. Some components have channels only on one layer while some have channels on both layers. Figure 37 shows a microfluidic valve from the Valves library.

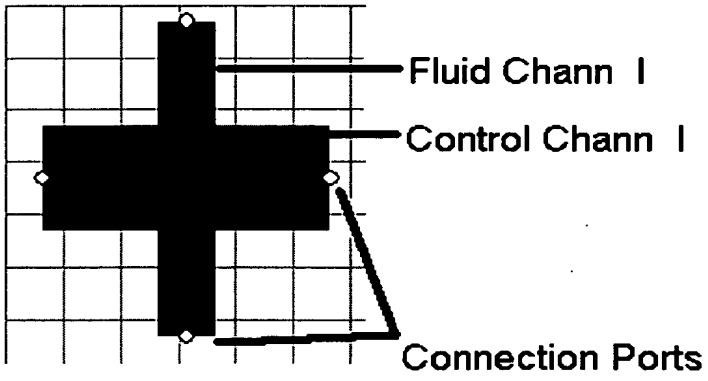


Figure 37 – Typical Library Component and Characteristics

The blue line represents a fluid channel present on the *Fluidic* layer while the red line represents a channel on the *Control* layer. The connection ports are points where connections from other components or drawn channels can legally be connected to the component.

> **Note:** Channel or component connections to connection ports of components MUST be members of the same layer.

Layer Manager

The Layer Manager serves to indicate the coloring of the layers as well as the different channel heights that are available in the particular layer. Currently only two layers are available at this time. The Layer Manager can be used to select the "Active" layer such that any drawn channels are added to that layer, change the coloring of the layer, and display or hide a layer from the active drawing area.

Figure 38 shows the Layer Manager window and the highlights the information available from the Layer Manager window.

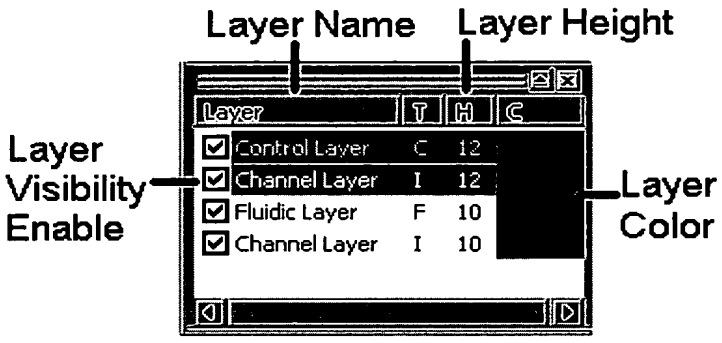


Figure 38 – Layer Manager

Layer Color

The default layer color is blue for the fluidic layer and red for the control layer. These colors can be changed to suit your preference.

Setting the Active Primary Layer

As mentioned above, the "Active Primary Layer" can be set through the Library Manager. Figure 39 shows the pop up after selecting the *Control* or *Fluidic* layer by left clicking to select it in the Layer Manager. Once selected, right clicking will bring up a pop up dialog box allowing you the ability to set the layer to be active.

Setting the layer to be active enables the following:

- Drawing of channels onto that layer.
- Selecting channels or components that are on that layer and performing actions on those selected.
- Changing the color of the layer. Any new color selected will replace the existing color for all components and channels in that layer.

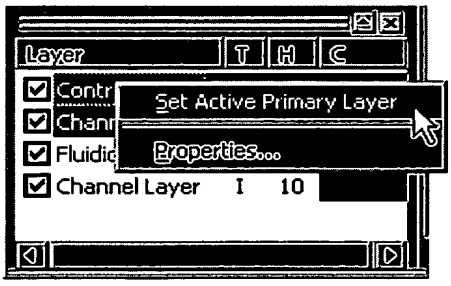


Figure 39 – Setting the Active Primary Layer

Active Drawing Area

The active drawing area is where components from the library are placed and connected together using the *Drawing* tools.

Rulers and Grid
The rulers displayed in the active drawing window displays the absolute location from (0,0) which represents the top left hand corner of the chip template. Figure 40 shows an example of the rulers and the grid from the active drawing window.

The lower right hand corner represents the (20000, 20000) position. These position numbers also translate into real measures as they are represented in microns. The grid color and the interval of grid lines can be changed using the *Grid Properties* command from the *View* menu.

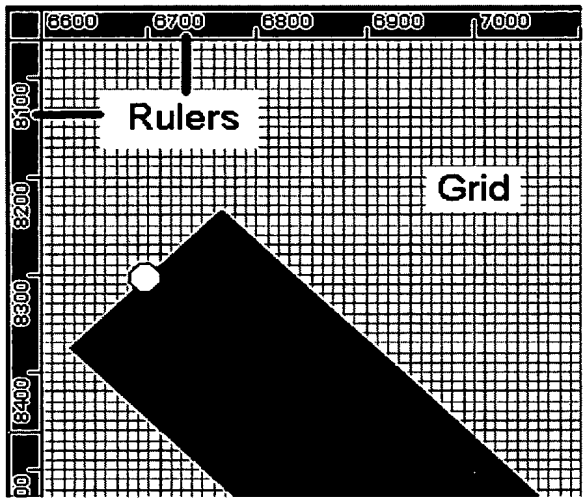


Figure 40 – Ruler and Grid from Active Drawing Window

Pop Up Menus
The active drawing area has right click pop up menus based on the function that is currently selected. There are two different pop up menus, one for the Select tool and the other for a selected component.

Select tool ( ) enabled Pop Up Menu

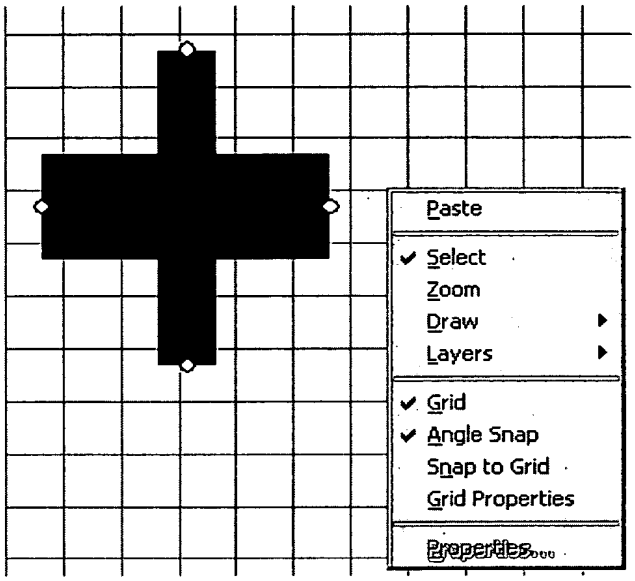


Figure 41 – Right Click Pop Menu with Select Tool Enabled

The pop up menu contains some of the most frequently used commands from the tool bar with the addition of the *Layers* command. The *Layers* command can be used to set active the layer you need to draw on without having to go to the Layer Manager. Figure 41 shows the submenu to select and set active a layer.

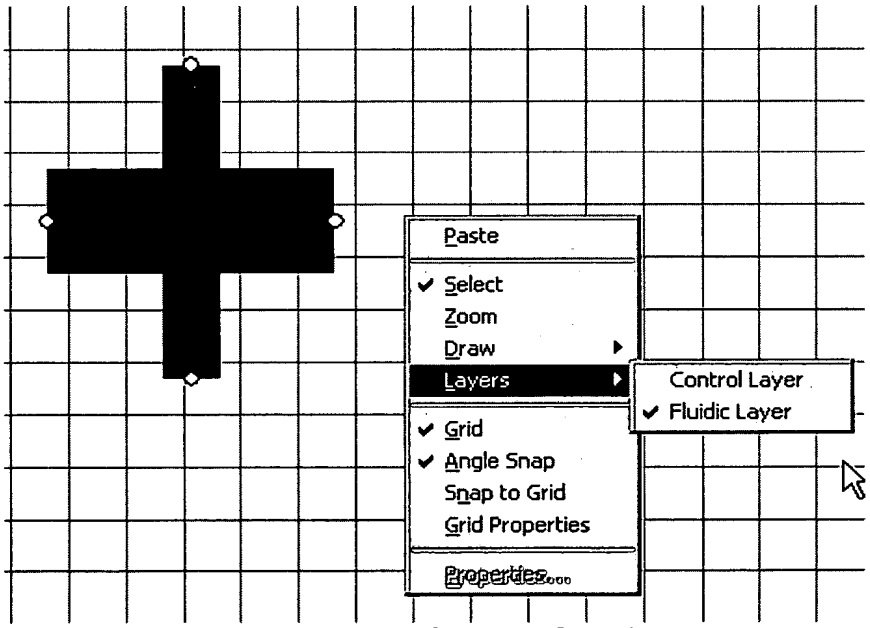


Figure 42 – Layer Submenu Selection

The check mark next to the layer name indicates the layer that is currently selected.

Selected Component/Channel Pop Up Menu

Once a component(s) or channel(s) is selected in active drawing area, a right click will pop up a menu to allow functions or commands to be performed on the selected objects.. The pop up menu is context sensitive in that a selected component will bring up a different pop up menu as opposed to a selected channel. Figure 43 shows a component selected and the pop

commands available. The function descriptions can be found in the Main Menu or Toolbar commands with the exception of the *Properties...* command

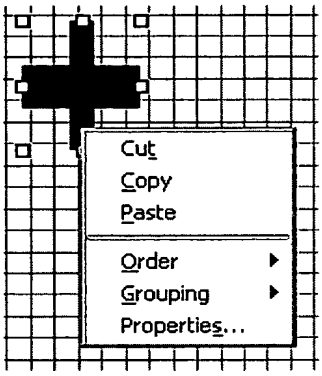


Figure 43 – Selected Component Pop Up Menu

Figure 44 shows a channel selected and the pop up menu with its available commands. Notice here the addition of the *Channel Widths* command. The Channel Widths command allows quick modifications of the drawn channels so that matching to connected components or channels is easily facilitated. Figure X shows an example where a channel drawn at 50 um needs to be connected to a pump control element that is 200 um in width.

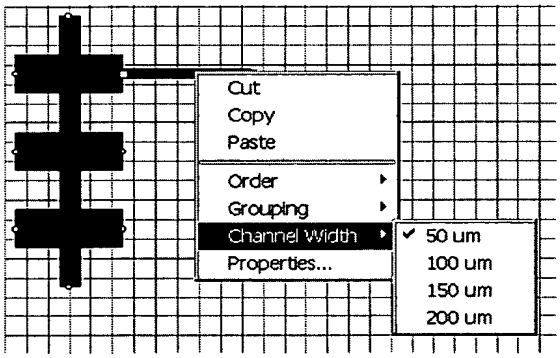


Figure 44 – Selected Channel Pop Up Menu

Status Bar

The Status Bar has two modes. One mode is when the drawing area is in the *Select* mode and the other is in the channel drawing mode.

Select Mode

In the *Select* mode the status bar contains the following information:

- Left Status Box: Component Name
- Center Status Box: Absolute Cursor Location (in microns)
- Right Status Box: Percentage Zoomed In

Figure 45 shows the Status Bar while in the select mode.

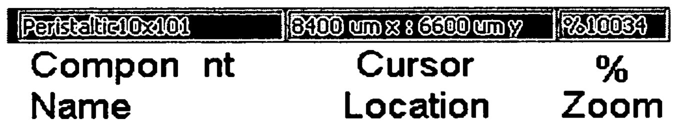


Figure 45 – Status Bar in Select Mode

Drawing Mode

In the *Drawing* mode the status bar contains the following information:

- Left Status Box: Length of channel drawn (in microns)
- Center Status Box: Absolute Cursor Location (in microns)
- Right Status Box: Percentage Zoomed In

Figure 46 shows the Status Bar while in the select mode. Notice as you start drawing the channel the status bar is updated with the length of the channel drawn.

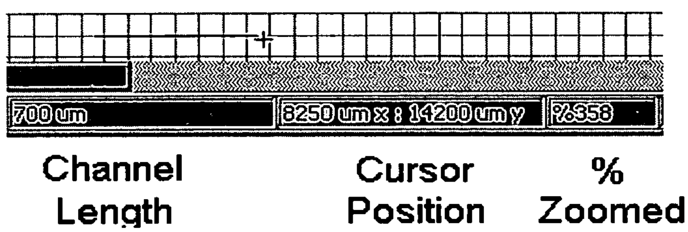


Figure 46 – Status Bar in Drawing Mode

Chapter 4 - Creating a Design

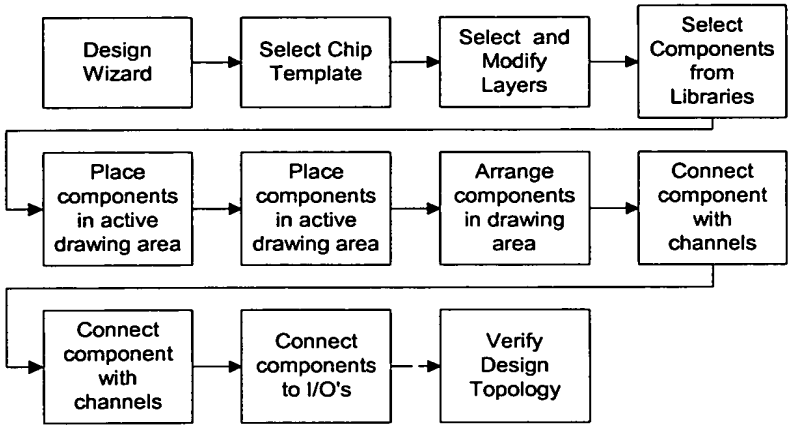


Figure 47 – Design Creation Block Diagram

General Rules For Design Implementation

FluidArchitect was built with many design rules that are implemented directly into the various parts of the design system. As such, FluidArchitect applies those design rules to your design as you are placing and connecting the components from the libraries in the drawing area. The following are general rules to keep in mind and will help lead to a successful design implementation.

- **Only library components delivered by Fluidigm can be used in a design.**
- **Do not overlap components. All components should be connected to other channels or other components via port connections.** (see *Connecting Components and Channels*)
- **Do not overlap channels.** Channels on the same layer or channels on different layers cannot be overlapped. User drawn channels must be used to connect other channels and components.
- **Only connect channels on the same layer and of the same width.** The set of components provided can be interconnected using the Channel tool. Depending on the layer, Fluidic or Control, a choice of channel widths is provided. Be sure to select the proper width for your connection.
- **Use common sense for placement of components.** Some components require more connections than others. Plan your design carefully so that you are not route restricted to where your components cannot be connected to due to other connection requirements.

Design Wizard

The Design Wizard walks you through the setup of the design and will allow you to set up the following details of your design:

- Design Directory
  The design database will be kept into the directory that you specify in this wizard screen, see Figure 48. You can change the final directory using the *Save* or *Save As...* command under the *File* menu.

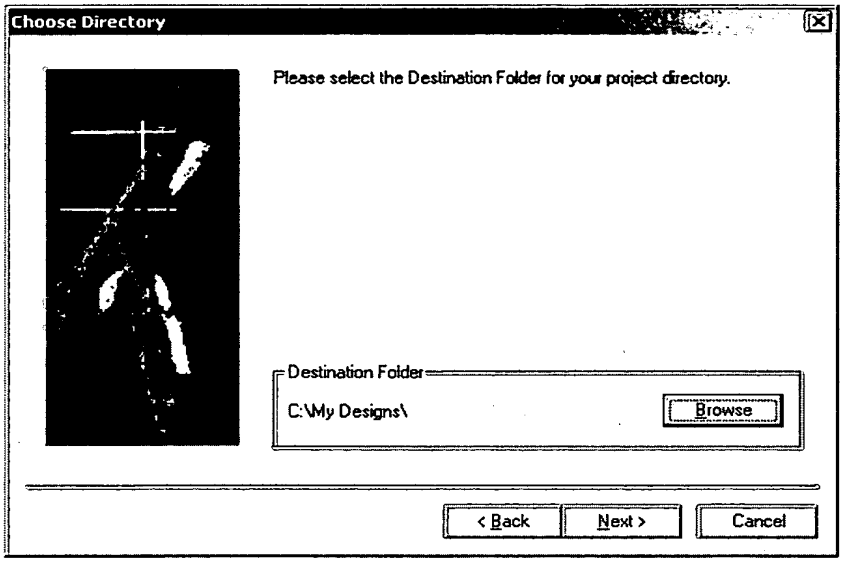


Figure 48 – Design Directory Selection Wizard Screen

- Chip Template Selection
  The appropriate chip template can be selected from this wizard screen, see Figure 49. As you click the < *Previous* and *Next* > buttons a thumbnail of the template will appear. Notice that the solid black circles represent where inputs and outputs will be placed and the number of each particular input and output size is shown to the right of the thumbnails. Currently, once you have selected a template it is not possible to change during your design process

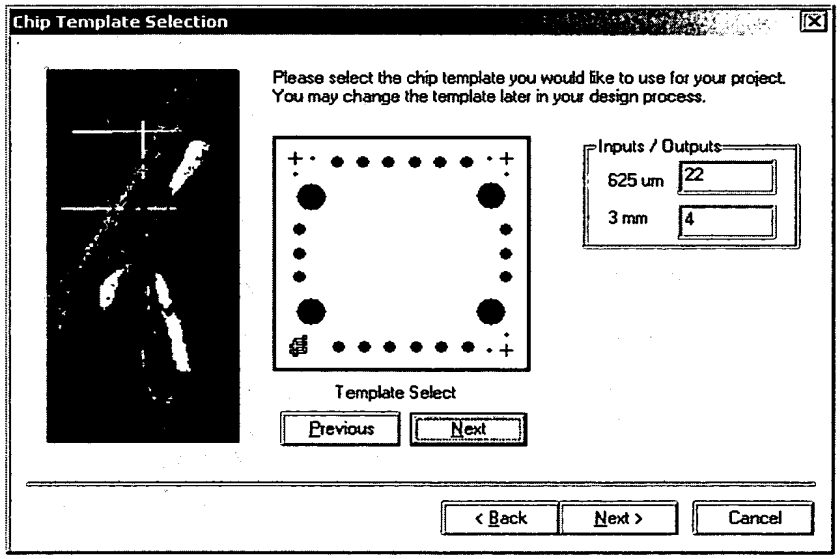


Figure 49 – Chip Template Selection Wizard Screen

- Layer Selection
  The layer selection screen, Figure 50, shows the number of layers that are available for use. The default is a pair of layers composed of the *Control Layer* and the *Fluidic Layer*. You can choose to deselect the layer by left clicking on the check box next to the layer name and the layer will be removed from the design. Note that after removal of this layer, active components will not be possible.

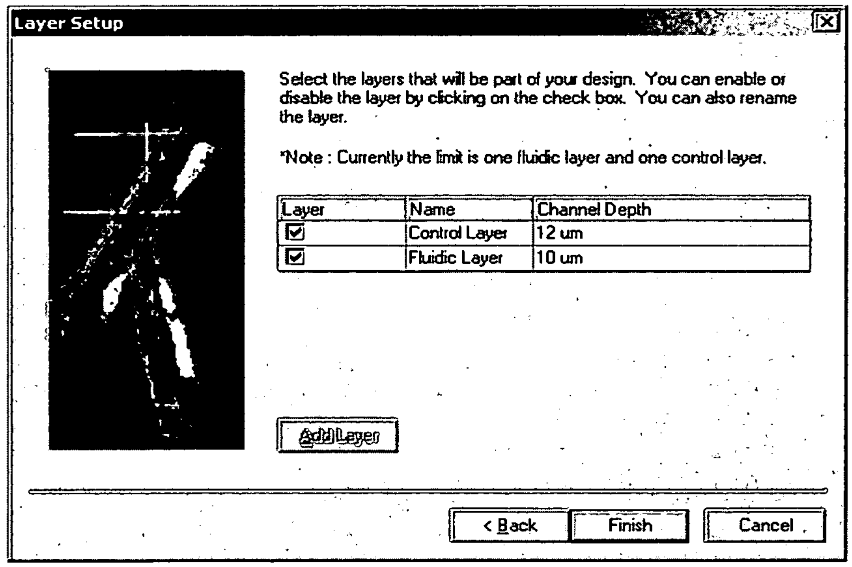


Figure 50 – Layer Selection Wizard Screen

Placing Library Compon nts

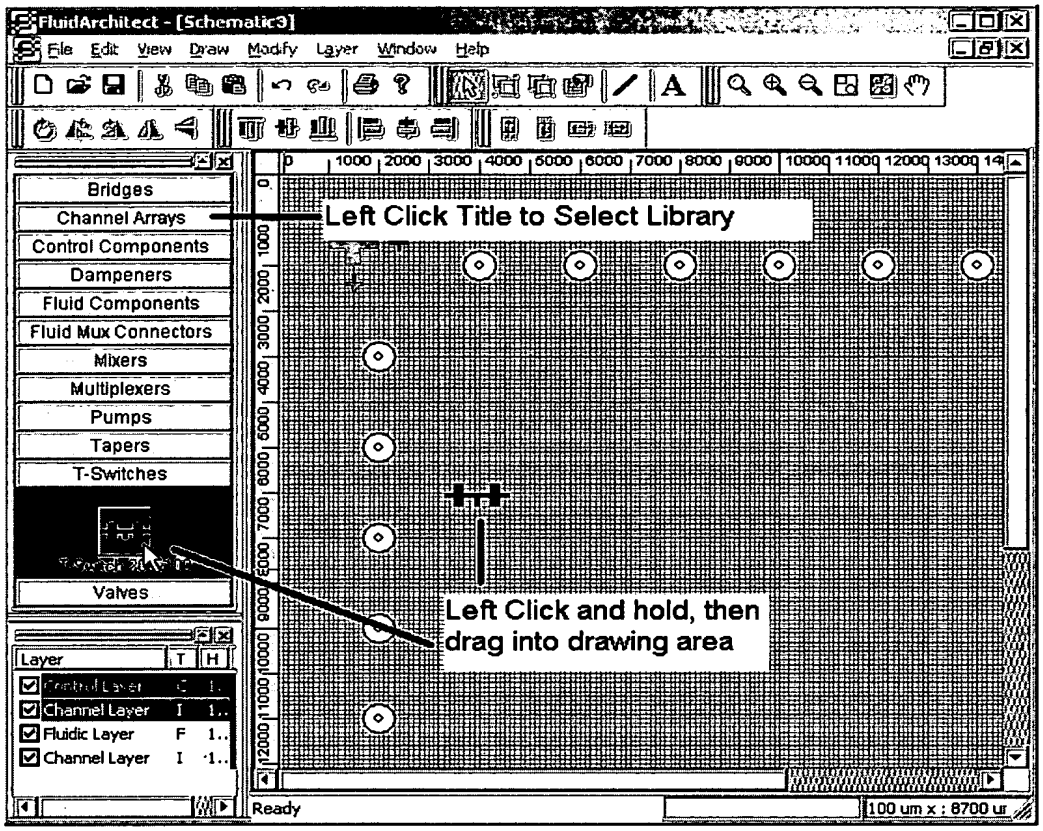


Figure 51 – Placing Components from the Libraries

The library contains a set of components that can be used in your design. Placement of the components accomplished by the following:

- Select the desired library by left clicking the mouse on the title of the library.
- Place the mouse over the desired component in the library window. The component will become selected and outlined.
- Left click and hold the mouse on the selected component and drag the component into the drawing area.
- Position the component where you would like to place it and release the left mouse button. The component will now be placed.

Figure 51 shows the process of placing the component from the library into the drawing area.

Note that the libraries provided are built specifically for use with our fabrication process. The components cannot be modified in any of its absolute dimensions. You only have control in its placement and its rotational position. If the component is rotated it should only be rotated in increments of +/- 90 degrees. Rotating using the free rotation tool can cause the component to become off grid and thus prevent it from being connected to other components or channels.

Ports of Chann Is and Components

After you have successfully dragged and dropped components onto the drawing area, the next step will be to connect the ports of the components with channels. Figure 52 shows the ports of a typical component.

- Ports are shown on components as black outlined white circles.
- Ports once successfully connected they appear as black filled circles. See Figure 53.
- Zooming in can help identify the ports on components and channels.

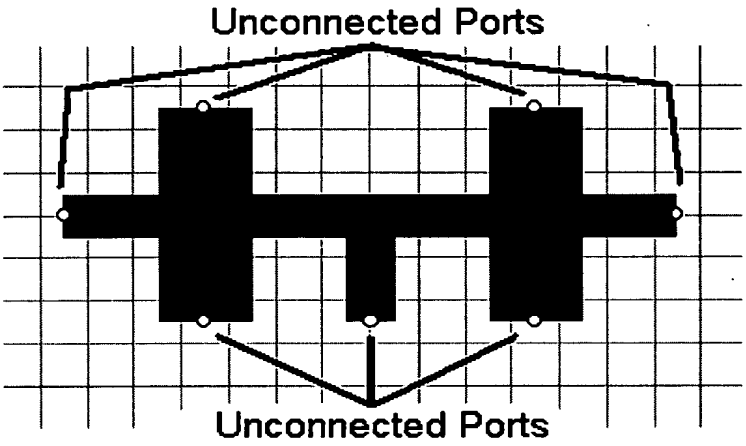


Figure 52 – Ports of a Component

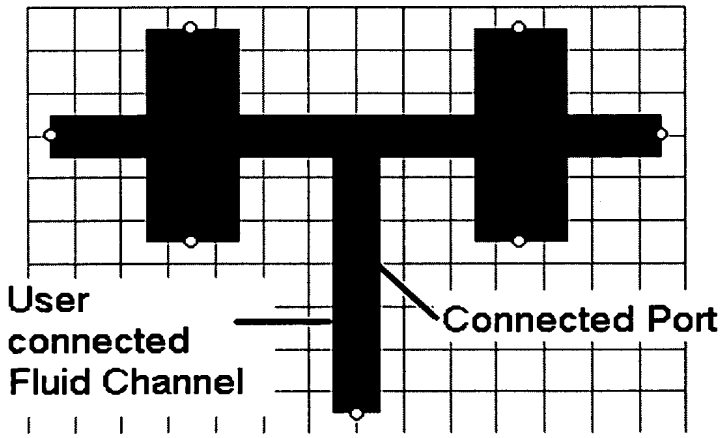


Figure 53 – Fluidic Channel Connect to a Component

Drawing Channels

Drawing channels to connect to other channels and components can be accomplished using the Draw Channel tool. Components are built up using channels in specific placement and physical dimensions. Thus, drawing channels to connect to components is the same as connecting to other drawn channels. The following are guidelines to keep in mind while drawing channels to make connections:

- Fluidic channels can only be connected to other fluidic channels.
- Control channels can only be connected to other control channels.
- Fluidic and Control channels cannot be drawn to overlap or cross each other.
- A 100um minimum separation between channels regardless of which layer the channels are members of.
- Only one layer can be set as "Active" so that any drawn channel is placed onto that layer.
- Widths of connecting channels must be the same.
- Channels can only be drawn orthogonally or parallel to the channel it is to be connected.

Procedure for Drawing a Channel

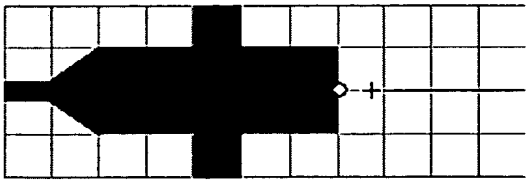
The *Channel* command under the Draw menu is used to enable the active drawing area for drawing channels. The following are the basic features to drawing channels.

- Selecting the Draw Channel command
- Left clicking to start one end point of the channel and dragging mouse to the location of the end point and double left click to end the channel.
- Single left clicking while drawing the channel will place vertex in the channel so that you can draw orthogonally from the placed vertex.
- Right clicking while drawing a channel will cancel the channel.
- When the drawn channel is within the "auto connect" area of a port or Input/Output, the cursor becomes a target (see *Target Tool* section). Left clicking twice will cause the drawn channel to become automatically connected.

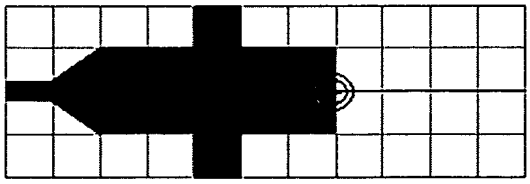
Target Tool

Connecting channels to other channels and components is facilitated by the *Target Tool*, which is automatically engaged when drawing channels for interconnections. Figure 54 shows a channel being drawn from the right to left towards the unconnected port.

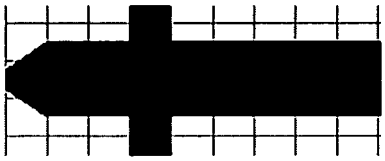
Figure 54a shows a channel being drawing towards the input of a component with the cursor identified as the "+" symbol. Figure 54b shows the cursor detecting a port on the component or channel and changing into a "target" cursor. When the target cursor is present you can double click the left mouse button and automatically the interconnection to the port of the channel or component. The result is shown in Figure 54c. where the port has turned black indicating that the port was successfully connected.



a.



b.



c.

Figure 54.a Channel Port Not Detected, b. Channel Port Detected, c. Channel Connected to Port

Input and Output Ports

The input and output ports, more commonly referred to as "I/O's", are the large circular figures on the template of the chip. Typically the I/O's are found near the perimeter of the chip. The I/O's are predetermined based on the template chosen in the Design Wizard.

I/O Ports are used to accomplish the following:

- Provide connections to fluid and material input and output from the chip.
- Provide connections to the control channels to input control signals such as air pressure.

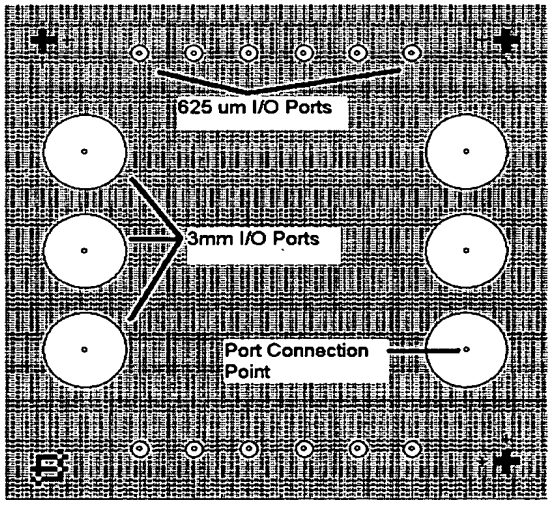


Figure 55 – Chip Template with 6 – 3mm and 12 – 625um I/O Ports

Figure 55 also shows a typical chip template with a preset I/O configuration. The connection point for each of the ports is illustrated in the figure as well. The connection point is the smaller concentric circle that is inside of the port. Connecting a channel to a port is can be accomplished by drawing a channel from a channel and when the target tool is engaged over the port, double left clicking the mouse will attach the to the I/O. Once successfully connected to the I/O, the I/O will turn blue and the inner circle will become a filled black circle. Figure 56 shows a connected I/O.

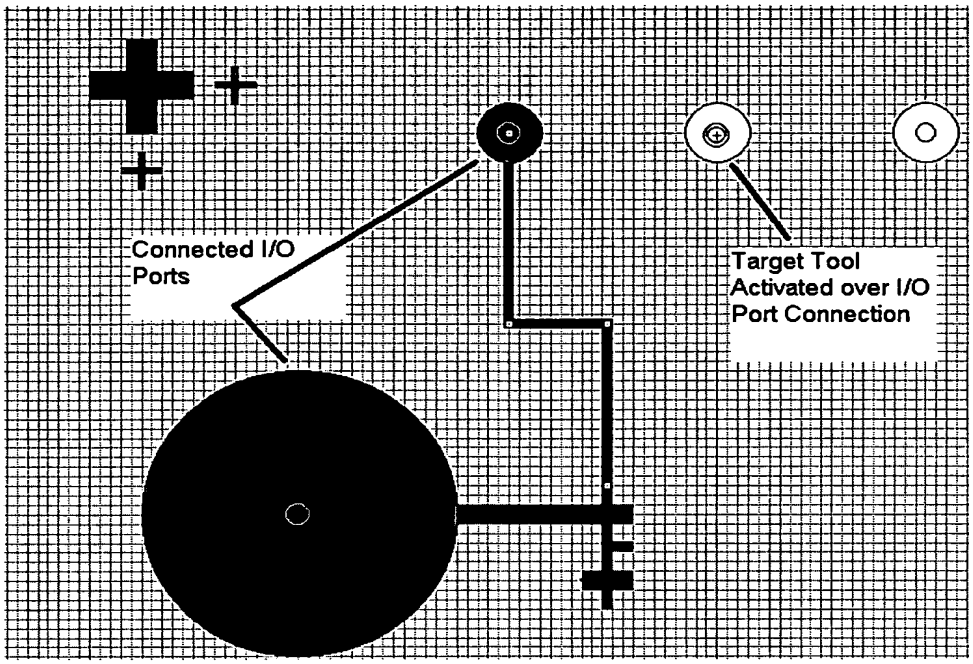


Figure 56 – Connected and Unconnected I/O Ports

Channel Properties

Components and channels can be assigned user defined names by accessing the Properties sheet for the component or channel. Channel Properties can be used to accomplish the following:

- Change Channel Instance Names
- Change Channel Widths (Fluidic and Control)
- List the connections to other components or channels

Figure 57 shows the channel dialog box for a selected control channel. You can change the width to any value in the drop down box as well as assign a new name to the channel. The channel is not currently connected to any other channel or component so the *Connections* list is empty.

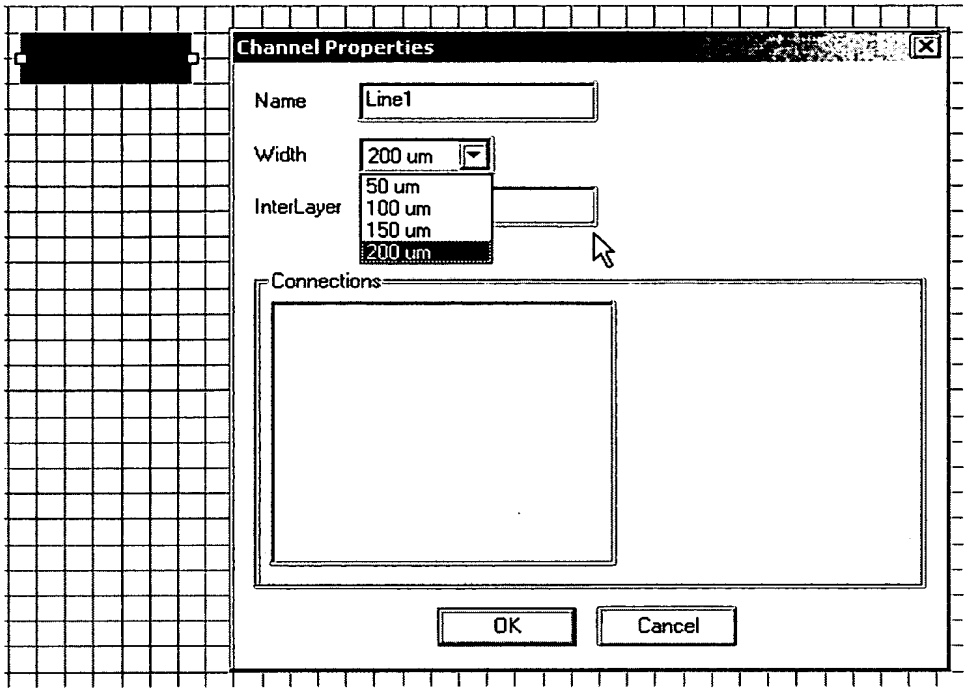


Figure 57 – Channel Properties Dialog Box

Component Properties

Library components are assigned a default name in the design. You can assign your own instance name to these components, as well as I/O's, to help identify them in the design.

Figure 58 shows a selected T-Switch that was placed from the library. To bring up the Properties dialog box do the following:

- Right click on the T-Switch and select *Properties…*

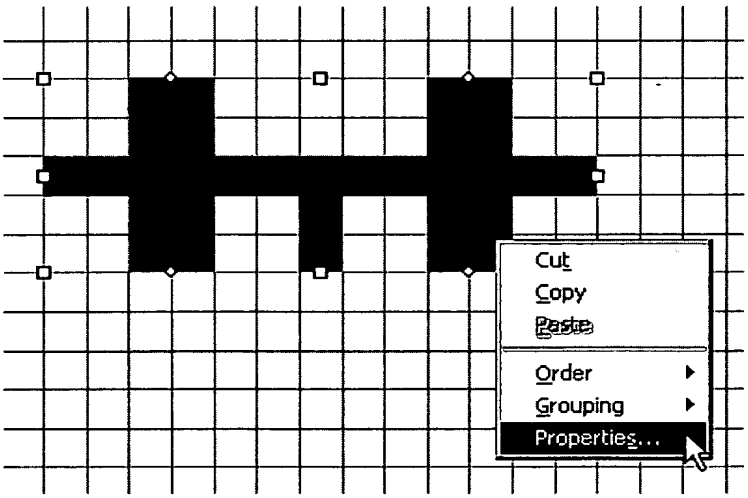


Figure 58 – Select a component and view properties

- The Component Properties dialog box will appear. In this case, this component has been named "*My_T-switch*". Figure 59 shows that type of component as well as two other tabs that contains placement information regarding the component.

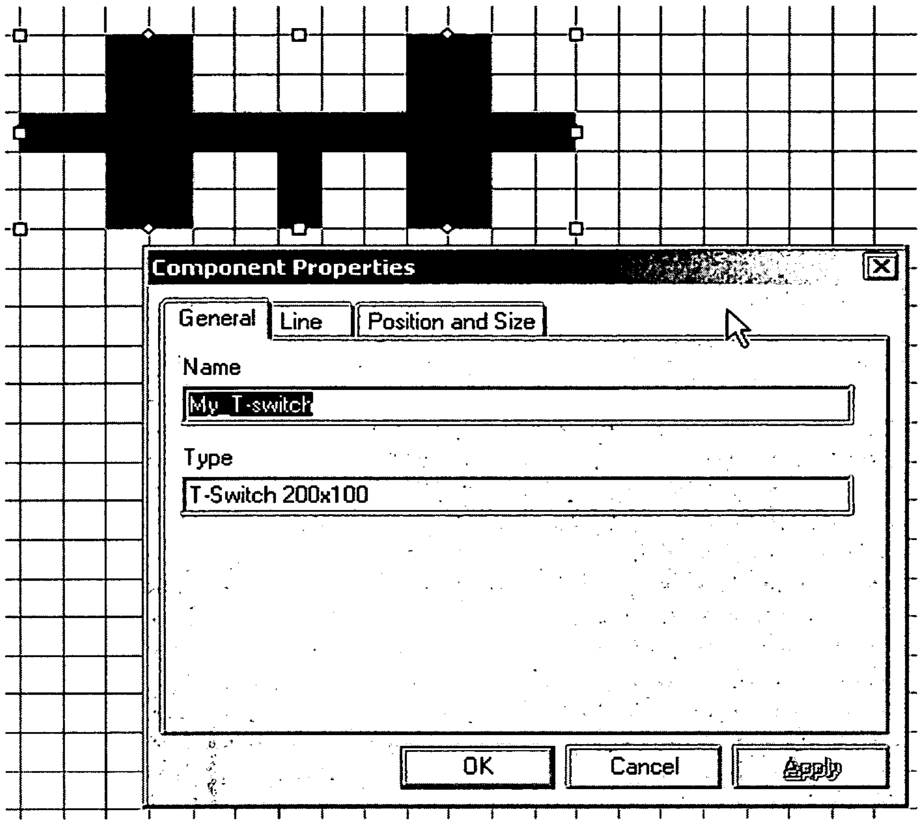


Figure 59 – Component Instance Property Dialog Box

Design Example

In the following design example a simple cell sorter, shown in Figure 60, is created using FluidArchitect. The pump drives into a T-Switch. The T-Switch is used to drive the fluid/material flow into one of two ports based on the detection region feedback to a system, which monitors and controls the flow. The design will illustrate the methods and procedures used to create the design in FluidArchitect.

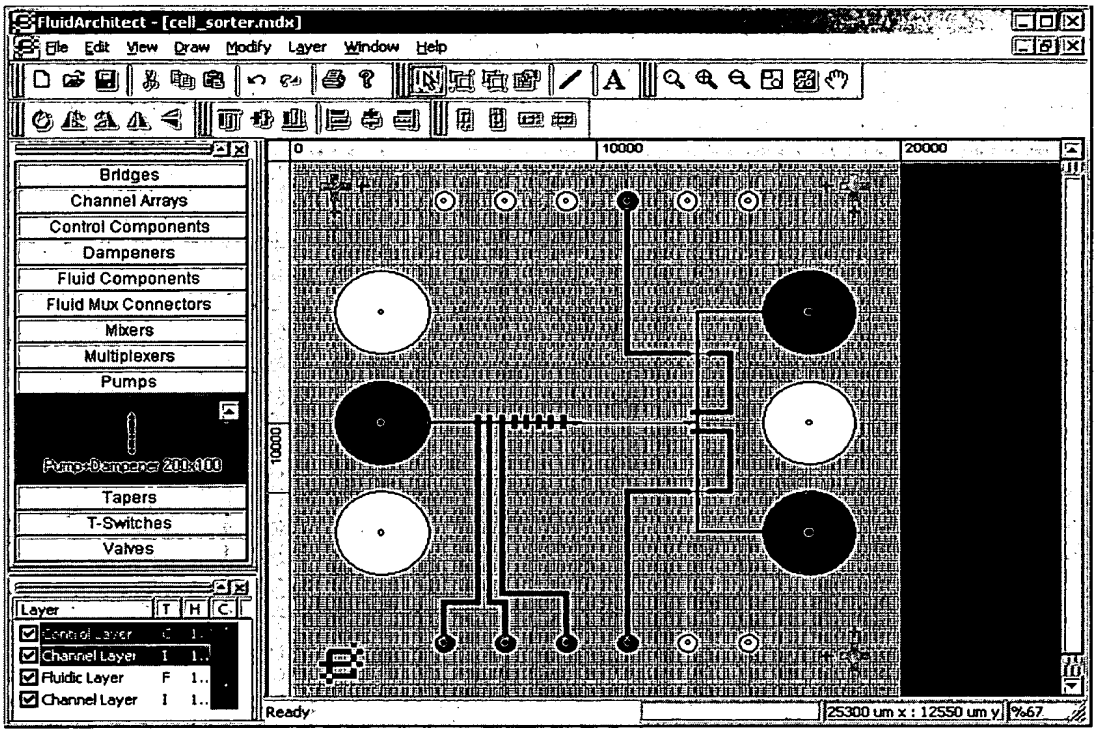


Figure 60 – Completed Design of the Simple Cell Sorter

Components Required

The components required to construct the simple cell sorter are:

- 1 - Peristaltic Pump
- 1 - T-Sorter
- 2 – 30 um–100 um Fluidic Tapers
- 2 – Bridges
- 3 – 3 mm I/O Ports
- 5 – 625 um I/O Ports

Basic Operation of the Design

Figure 61 shows the pump, T-Sorter, and the bridges connected in the drawing area. There are many ways to connect the components together and if the design rules are not violated the design will be valid.

Figure 61 also points out a "Detection Region". This region can be used by an optical detection system to control the direction of the flow through the T-Sorter. The detection region is not a component from the library but rather a user drawn 30 um fluidic channel connecting fluidic taper components forming the region.

Cells are pumped through the channel from the 3mm input port on the left side of the chip using the three control valves and five damping elements that constitutes the pump. An

external detection system, such as an optical measuring system, detects cells as they flow through the "Detection Region". The cells can be directed in either direction to the 3mm output ports by actuation of the T-sorter valve switches. The Bridge components are used to enable the crossing of fluid lines by control lines without creating a parasitic valve. The Bridge components were used in this design to create an area clear of channels for the "Detection Region".

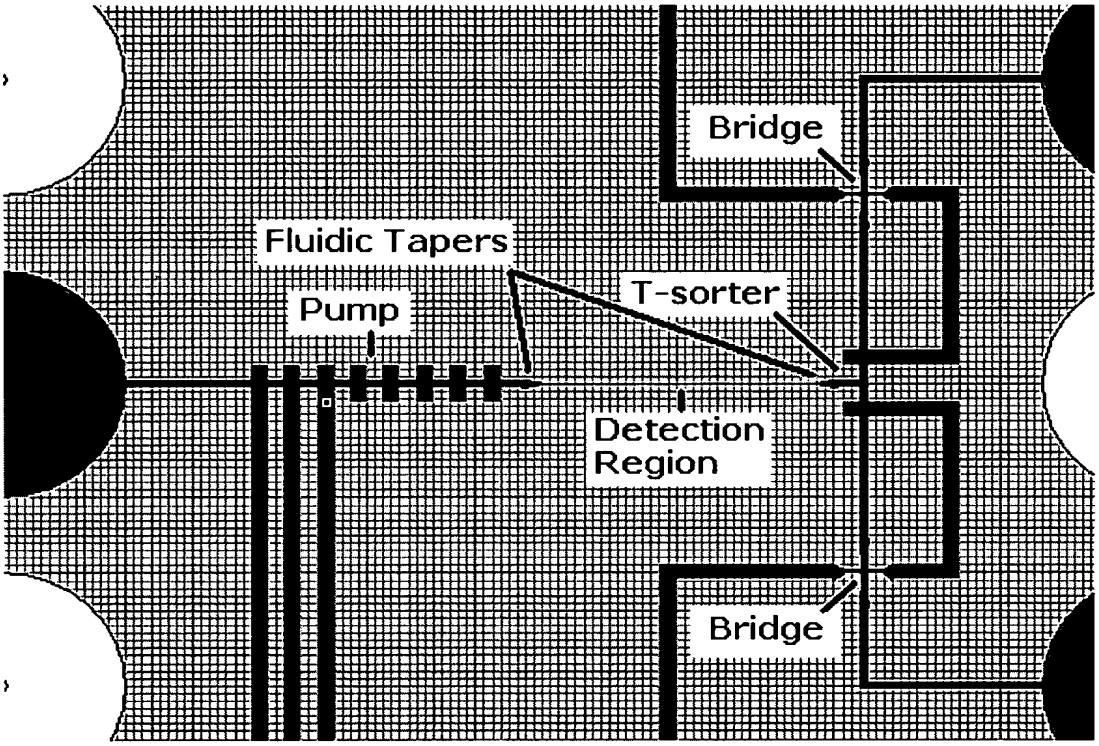


Figure 61 – Components of the Simple Cell Sorter

Creating the Design

Start the design by launching FluidArchitect from the *Start* menu > *FluidArchitect* > *FluidArchitect* on your PC.

Once the FluidArchitect is started, the next step is to select *File* menu > *New*. The design wizard will start and guide you through the setup for a new design.

Design Wizard Setup

The Figure 62 shows the Design Wizard screens as they appear in order querying for selections. Carefully read the screens shown by the Design Wizard to appropriately setup the design. Failure to setup the design correctly could lead to reiterations of the design to get the desired results.

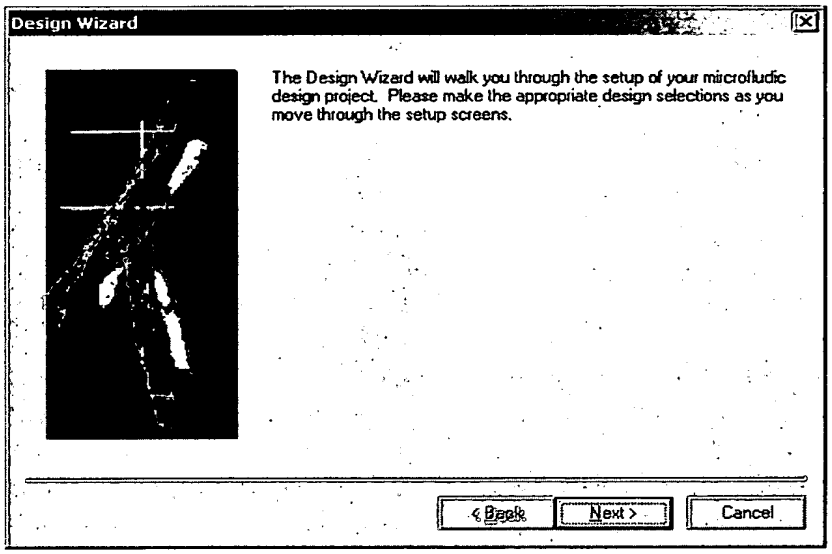


Figure 62 – First Design Wizard Screen

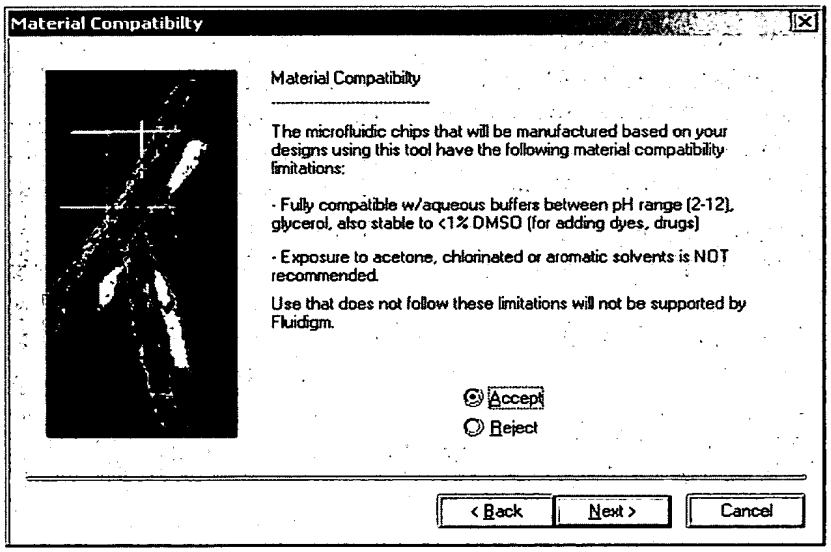


Figure 63 – Material Compatibility Design Wizard Screen

The material compatibility screen warns you to the materials that can and cannot be used with the microfluidic chips that are designed with the FluidArchitect system and fabricated by Fluidigm. Selecting "Accept" will allow you move forward with the design setup. If your needs are not met and you "Reject" the Design Wizard will not go forward. Please contact the factory for more details regarding your special needs.

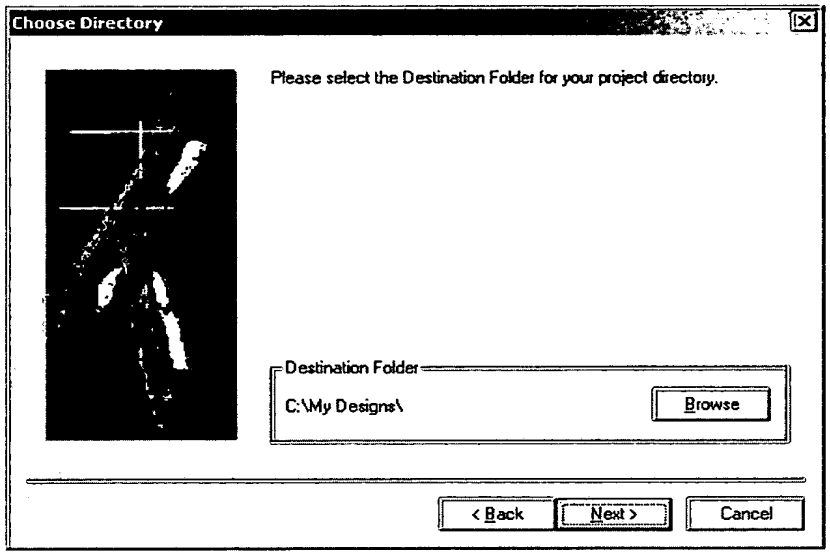


Figure 64 – Project Directory Selection

The Project Directory selection screen simply selects the directory where your design database will be stored.

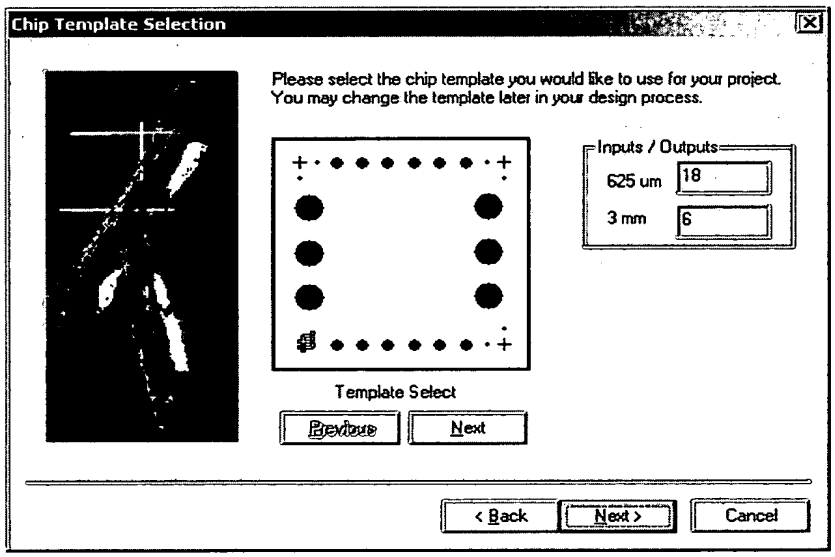


Figure 65 – Chip Template Selection

The chip template selection is very important. Please consider your design and how many inputs and outputs are needed. There are several templates to choose from and the number of 625 um and 3 mm input/output ports are shown in the page as you select the template need. Currently it is not possibly to change chip templates in the middle of a design.

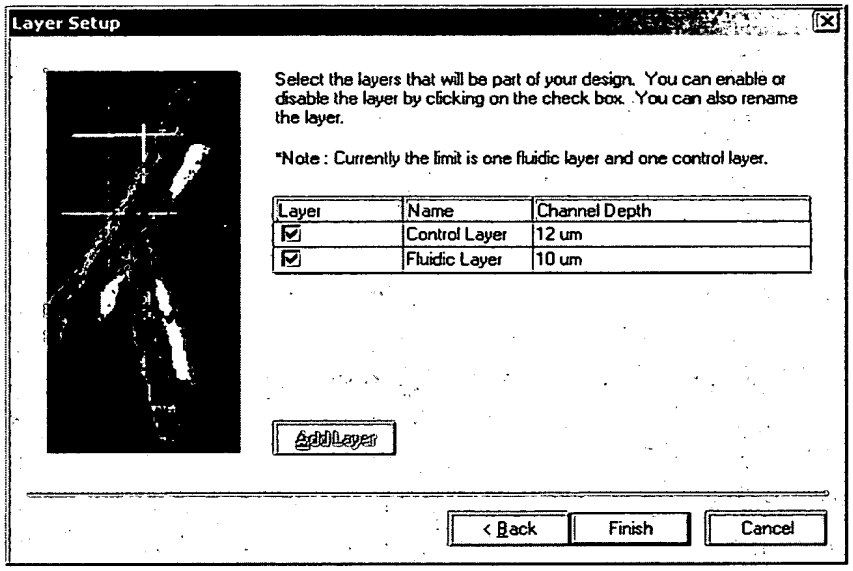


Figure 66 – Layer Setup

The layer setup page allows you to select the layers needed in your design. By default two layers are selected and this is necessary to create active fluidic circuits on the chip. Currently the system is restricted to having a maximum of two layers. Each layer has a channel depth associated with the layer that is fixed in depth.

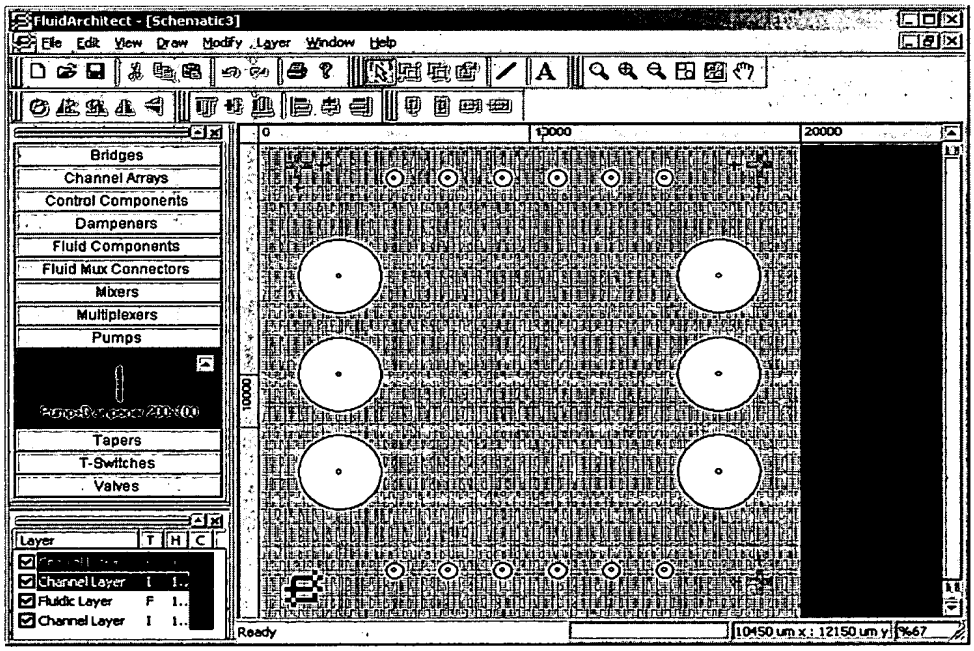


Figure 67 – Completed Design Wizard Setup View

Once you have completed the Design Wizard the chip template chosen will appear in the drawing area as shown in Figure 67. The library components are ready for selection and placement into your design. The layer manager indicates the color of the channels and two which layer they belong as well as the current "Active" layer which is highlighted in black.

Placing Components

Simply select the library from which to drag and drop the components and place them into the drawing area. Left click on the T-Switches title bar in the Library Manager to select the library. Figure 68 shows the T-Switch library being selected and the T-Switch being placed into the drawing area. As the T-Switch is being dragged and positioned it appears as outline of dashed lines. Once placed

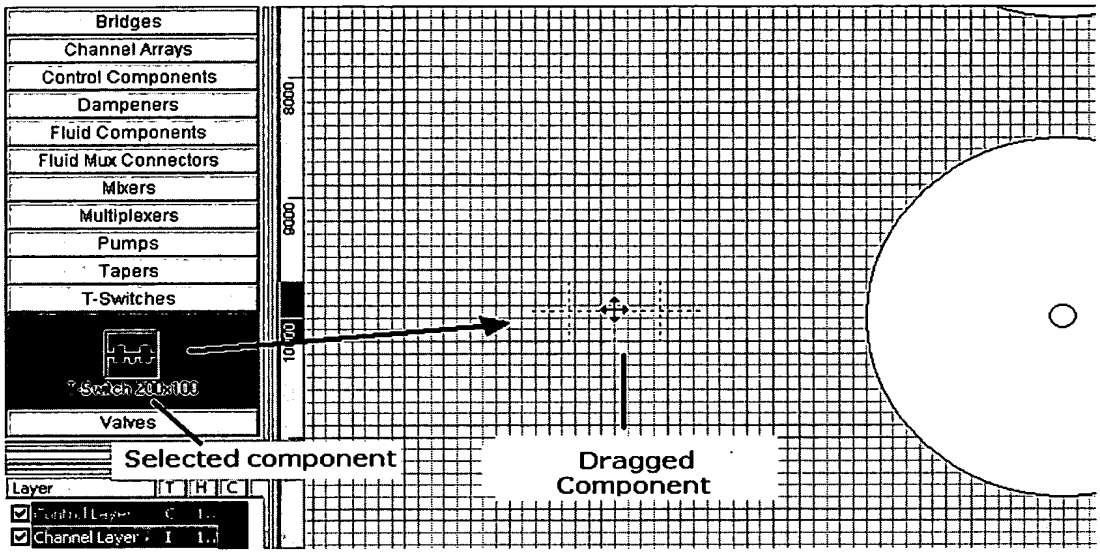


Figure 68 – Placing the T-Switch Component

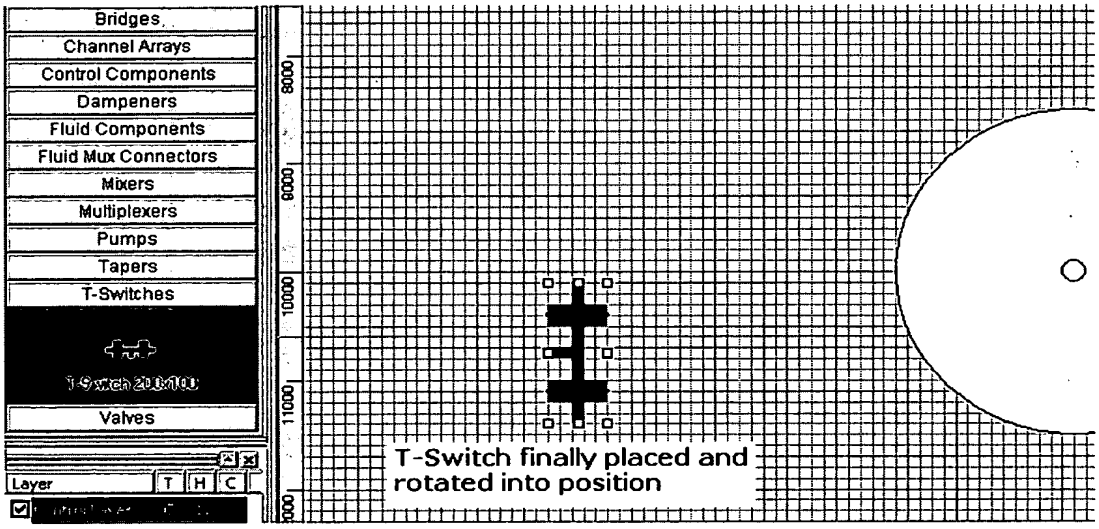


Figure 69 – Finally Placed T-Switch

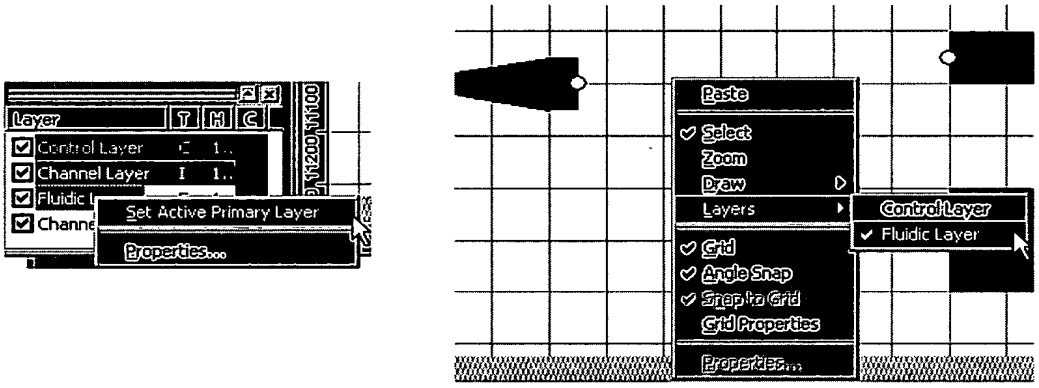
The placed T-Switch component can now be selected by left clicking it. Once selected, it can be rotated or positioned depending on what is required.

Now, the steps above should be repeated to place the rest of the components for this design.

Conn cting the Compon nts

Once all of the components are placed, they must be connected. The components typically consist of channels from both the fluidic and control layers that are specifically positioned and dimensioned to insure proper operation.

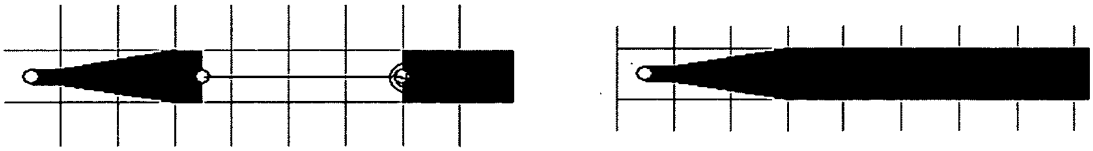
Figure 70 shows the connection of the T-Switch to the "Detection Region", which consists two taper elements and a 30 um channel connecting between the two tapers. Recall that to select a component that only has channel in either the fluidic or control layer, the fluidic or control layer must be set "Active". This can be done in the Layer Manager by left clicking on the desired layer and right clicking to bring up the pop up menu to set the layer "Active" OR this can also be done by right clicking in the drawing area and bring up the pop up menu and selecting *Layer* > *Control* or *Fluidic*.



a b

Figure 70. a. Selecting the "Active" Layer through the Layer Manager, b. Selecting the "Active Layer" through the right clicked pop up menu in the drawing area.

In this case the Fluidic Layer needed to be selected as the 30 um – 100 um Taper component was being connected to the input of the T-Switch. Figure 71 shows a channel being drawn from the right end of the Taper component to the input of the T-Switch. Once the cursor turns into the Target Tool a left click will cause a channel to be connected to the unconnected port.

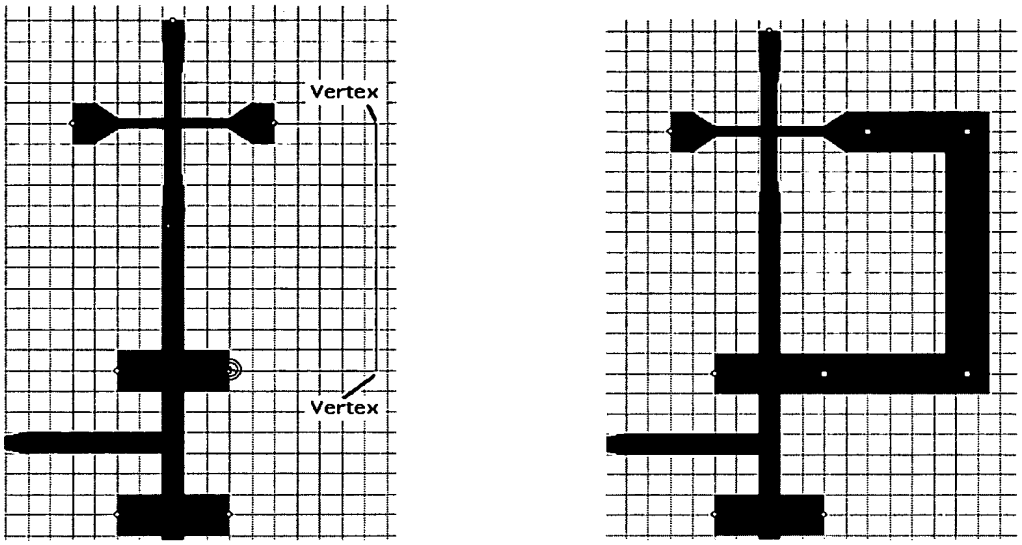


a. b.

Figure 71 – a. Drawing a Fluidic Connecting Channel, b. Successfully Connected Channel.

Adding a Vertex While Drawing a Channel

While you are drawing a channel, you can single left click to place a vertex from which you can continue to draw a straight channel or draw the channel orthogonally from the placed vertex. Figure 72 shows an example of how to place a vertex and draw a channel with an orthogonal continuation.



a b

Figure 72 – a. Drawing the control channel and placing the two vertices as shown. b. Completing the connection and the control channel.

Changing the Channel Widths

The width of the drawn fluidic channel was set to 100 um as the default. The default setting for a new design is 100 um for a user drawn fluidic channel and 200 um for a user drawn control channel. FluidArchitect will keep the default width setting until the user changes the channel width through selecting a channel and changing its width. Figure 73 shows the how the drawn fluidic channel is originally drawn as 100 um but needs to be resized to match the components that it connects to.

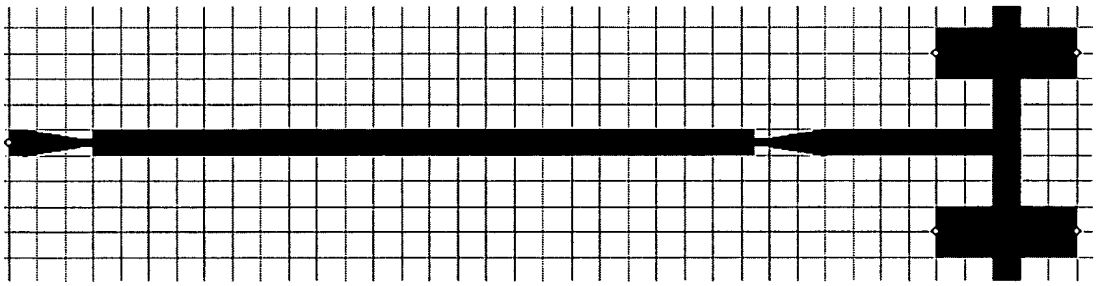


Figure 73 – Drawn Channel Not the Correct Width for Connection

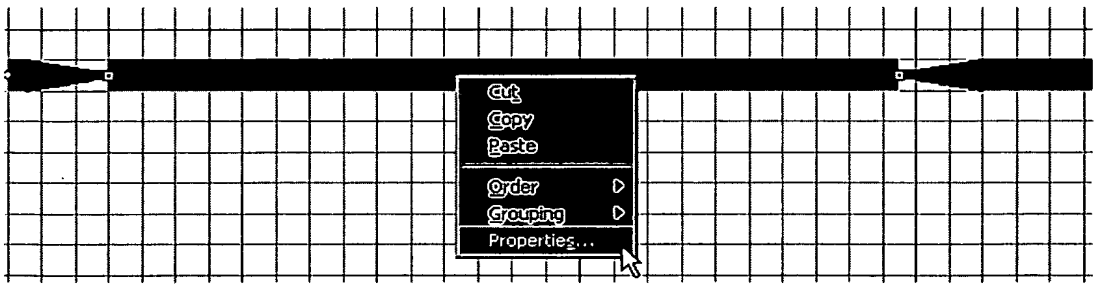


Figure 74 – Open the Channel Properties Dialog to Set Correct Channel Width

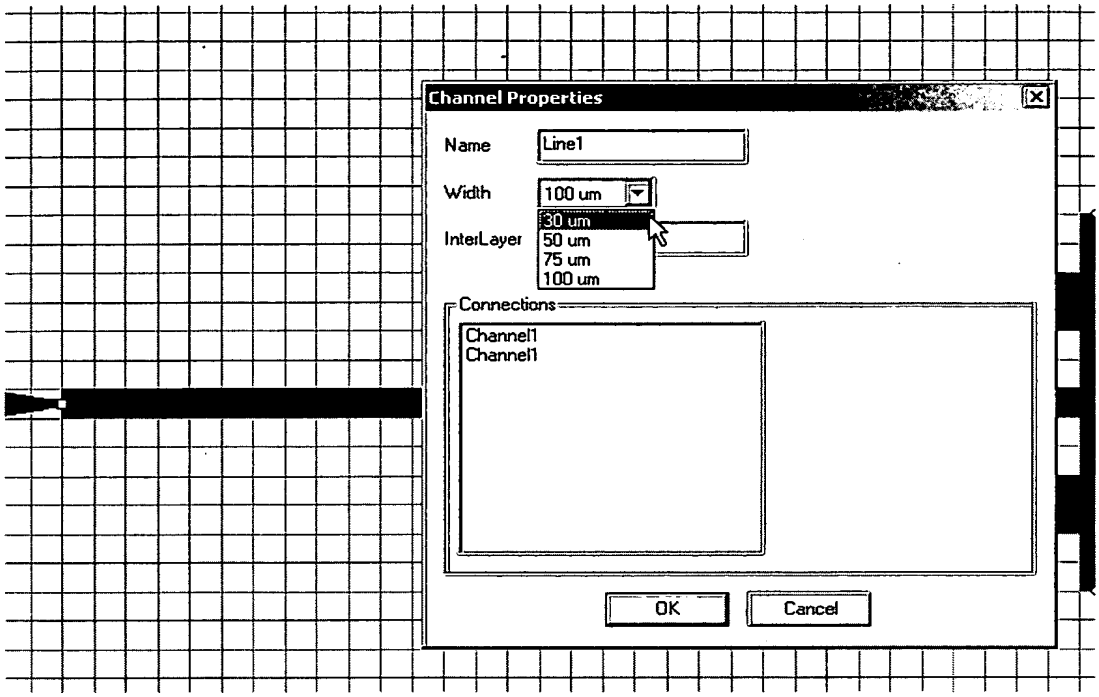


Figure 75 – Setting the Channel Width

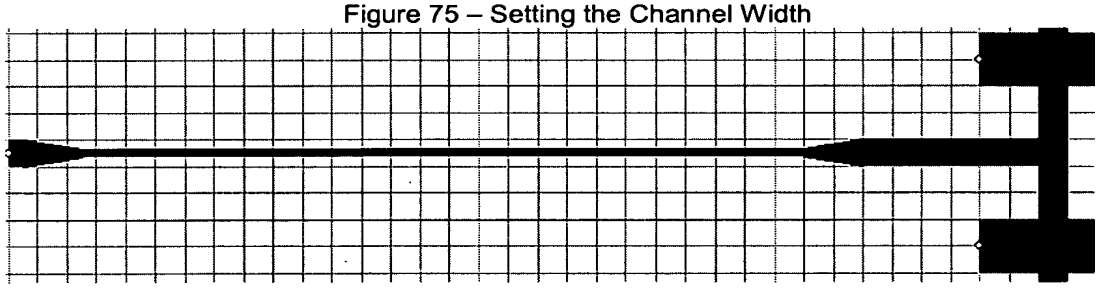


Figure 76 – Drawn Fluidic Channel Width is Now Correct

Connecting To I/O Ports

Once all of the components have been interconnected, the inputs and outputs (I/O) need to be connected. They are connected much in the same way that channels are connected with the help of the Target tool. Once the I/O's are successfully connected, the outlined ports will turn from white to black and the port will turn blue as well. Figure 77 shows an example of a successfully connected 625 um port.

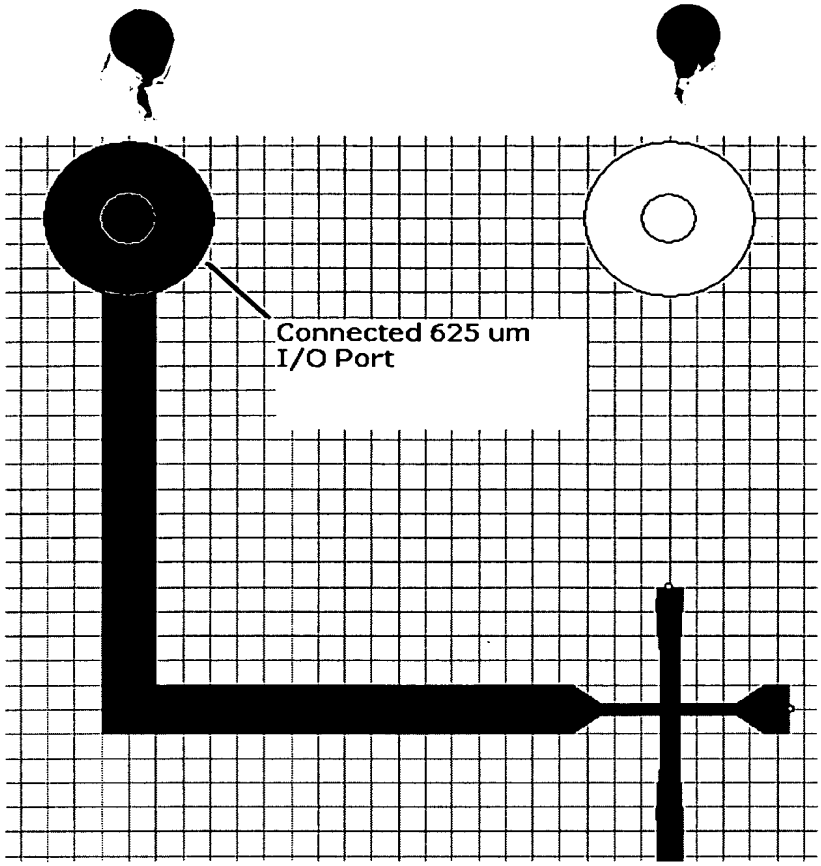


Figure 77 – Bridge Component Connected to an I/O Port

Conclusion

Using the techniques in the example design give above will help lead to successful microfluidic chip design using FluidArchitect. Recall, there are built in design rule checkers that will give you warnings and errors from time to time as you are designing based on what you are connecting and drawing.